RELIABILITY ABSTRACTS and TECHNICAL REVIEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Office of Reliability and Quality Assurance
Washington, D.C. 20546

1964
FOURTH VOLUME
Abstracts 1306-1695

PREFACE

In order to help scientists concerned with the reliability of parts, assemblies, components, and systems to stay abreast of the latest developments in the literature in this field, the National Aeronautics and Space Administration has since April 1961 sponsored the production of RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS. This, the fourth volume contains Serial Numbers 1306-1695, issued between June 1964 and December 1964. The contents of the previous volumes are as follows:

First, Serial Numbers 1-275 issued between April 1961 and May 1962
Second, Serial Numbers 276-775 issued between June 1962 and May 1963
Third, Serial Numbers 776-1305 issued between June 1963 and May 1964.

The work on this project is performed by the Research Triangle Institute, Durham, North Carolina under the sponsorship and supervision of the Office of Reliability and Quality Assurance of NASA. Current papers on reliability and closely related subjects are sought from all available sources, including technical journals, trade magazines, and proceedings of conferences and meetings. Authors of papers and technical reports in the field are invited to submit their material for inclusion in the service. Abstracts and reviews of the papers are prepared and submitted in monthly installments to NASA for distribution to a NASA mailing list. Prior to its submittal to NASA, each abstract and review is sent in draft form to the author (or first author) of the paper to enable him to make comments. The comments received are considered in preparing the final form of the abstract and review.

Each item in this volume has been classified as to subject according to the American Society for Quality Control Literature Classification System, Methodology or Techniques Classification, as revised in January 1963. A listing of the code numbers of this system, together with the subject-matter categories for which they stand, appears on page two. The codes assigned to the individual paper appear below the serial number on the corresponding abstract and review sheet, and are intended to represent not only the principal subject matter of the paper, but also areas in which the contents may be expected to be useful. To facilitate the search for material in given subject-matter categories, a listing has been prepared of the serial numbers of the papers to which the various codes have been assigned. This listing appears as the INDEX OF SERIAL NUMBERS BY CODES, on pages three through six.

000 GENERAL
- 010 QUALITY CONTROL DEFINITIONS / SYMBOLS
- 090 BIBLIOGRAPHIES

100 STATISTICAL PROCESS CONTROL
- 110 CONTROL CHARTS
  - 111 CONTROL CHARTS FOR VARIABLES
  - 112 CONTROL CHARTS FOR ATTRIBUTES
- 120 PROCESS CONTROL REQUIREMENTS
  - 121 SPECIFICATIONS
  - 122 TOLERANCES
  - 123 PROCESS CAPABILITY
- 130 FREQUENCY DISTRIBUTIONS IN PROCESS CONTROL

200 SAMPLING PRINCIPLES AND PLANS
- 210 PRINCIPLES OF SAMPLING
  - 211 BULK MATERIALS
  - 212 DISCRETE UNITS
  - 213 CLASSIFICATION OF CHARACTERISTICS
  - 214 SAMPLE SELECTION
- 220 SAMPLING PLANS
  - 221 SELECTION / COMPARISON OF SAMPLING PLANS
  - 222 ATTRIBUTES PLANS
  - 223 VARIABLES PLANS
  - 224 CONTINUOUS PLANS
- 230 CENSUSES AND SURVEYS

300 MANAGEMENT OF QUALITY CONTROL
- 310 INITIATION OF QUALITY CONTROL
- 320 TRAINING IN QUALITY CONTROL
  - 321 TUTORIAL MANUALS AND TEXTS
  - 322 TRAINING AIDS / DEVICES
  - 323 TRAINING PROGRAMS
  - 324 LICENSING / SKILL CERTIFICATION
- 330 ORGANIZATION FOR QUALITY CONTROL
  - 331 QUALITY CONTROL PERSONNEL
- 340 ADMINISTRATIVE TECHNIQUES IN QUALITY CONTROL
  - 341 RECORDS AND REPORTS OF QUALITY
  - 342 STANDARDS AND PROCEDURES
  - 343 INCENTIVE PLANS
  - 344 QUALITY INDICES
  - 345 QUALITY AUDITING SYSTEMS
  - 346 DRAWING CHANGE CONTROL
- 350 ECONOMICS OF QUALITY
  - 351 CUSTOMER-VENDOR RELATIONS
  - 352 QUALITY STANDARDS
  - 353 QUALITY COST MEASUREMENT

400 MATHEMATICAL STATISTICS AND PROBABILITY THEORY
- 410 THEORY OF ESTIMATION AND STATISTICAL INFERENCE
  - 411 POINT ESTIMATION
  - 412 CONFIDENCE INTERVALS
  - 413 HYPOTHESIS TESTING
  - 414 DECISION THEORY
- 420 PROPERTIES OF DISTRIBUTION FUNCTIONS
  - 421 NORMAL DISTRIBUTION
  - 422 POISSON DISTRIBUTION
  - 423 BINOMIAL DISTRIBUTIONS
  - 424 COMPOSITE / MULTIVARIATE DISTRIBUTIONS
  - 425 FITTING DISTRIBUTION FUNCTIONS
- 430 PROBABILITY THEORY
  - 431 STOCHASTIC PROCESSES
  - 432 QUEUING THEORY
  - 433 BAYESIAN METHODS
- 440 TRANSFORMATIONS

500 EXPERIMENTATION AND CORRELATION
- 510 TESTS OF SIGNIFICANCE AND CONFIDENCE INTERVALS
  - 511 SIGNIFICANCE TESTS
  - 512 CONFIDENCE INTERVALS
  - 513 STATISTICAL ANALYSIS
- 520 DESIGN AND ANALYSIS OF EXPERIMENTS
  - 521 PLANNING THE EXPERIMENT
  - 522 EXPERIMENTAL DESIGNS
  - 523 SPECIAL METHODS FOR ANALYSIS OF DATA
  - 524 ANALYSIS OF VARIANCE
- 530 CORRELATION
  - 531 SIMPLE CORRELATION
  - 532 MULTIPLE CORRELATION
  - 533 RANK CORRELATION
  - 534 COVARIANCE ANALYSIS
- 540 CURVE FITTING
  - 541 LINEAR REGRESSION
  - 542 NON-LINEAR REGRESSION
  - 543 MULTIPLE REGRESSION
  - 544 ORTHOGONAL POLYNOMIALS
  - 545 TIME SERIES
  - 546 GOODNESS OF FIT TESTS
- 550 SHORT-CUT METHODS OF ANALYSIS
  - 551 NON-PARAMETRIC TESTS
  - 552 GRAPHICAL ANALYSIS OF DATA
  - 553 TABLES
  - 554 CHARTS
  - 555 NOMOGRAPHS

600 MANAGERIAL APPLICATIONS
- 610 OPERATIONS RESEARCH METHODS
  - 611 COLLECTION OF OPERATIONAL DATA
  - 612 SPECIAL TECHNIQUES AND THEIR APPLICATION
  - 613 MANAGERIAL SYSTEMS ANALYSIS
  - 614 LINEAR PROGRAMMING
  - 615 DYNAMIC PROGRAMMING
  - 616 QUEUING THEORY
- 620 INDUSTRIAL ENGINEERING METHODS
  - 621 PACKAGING AND SHIPPING
  - 622 PRODUCTION SCHEDULING AND CONTROL
  - 623 WORK MEASUREMENT AND WAGE PLANS
  - 624 INVENTORY SCHEDULE AND CONTROL
  - 625 FACILITIES REPLACEMENT
- 630 BUSINESS ECONOMICS METHODS
  - 631 MEASUREMENT AND ANALYSIS
  - 632 FORECASTING / ESTIMATING
  - 633 FINANCIAL POLICY
  - 634 SALES CONTROL
  - 635 INDEX NUMBERS
- 640 PERFORMANCE MEASURING AND REPORTING (CRITICAL PATH)

700 MEASUREMENT AND CONTROL
- 710 MEASUREMENT OF QUALITY CHARACTERISTICS
  - 711 PHYSICAL PROPERTIES
  - 712 DYNAMIC PROPERTIES
  - 713 STRUCTURAL PROPERTIES
  - 714 CHEMICAL PROPERTIES
  - 715 ATOMIC AND NUCLEAR PROPERTIES
  - 716 AGING AND DETERIORATION
  - 717 ERROR OF MEASUREMENT
- 720 PROCESS CONTROL
- 730 DATA HANDLING
  - 731 DATA COLLECTION
  - 732 DATA REDUCTION
  - 733 DATA PROCESSING
  - 734 DATA STORAGE
  - 735 DATA RETRIEVAL
- 740 AUTOMATION
- 750 SENSORY MEASUREMENTS
  - 751 VISUAL / SIGHT
  - 752 TASTE
  - 753 SMELL
  - 754 TACTILE / TOUCH
  - 755 AUDIO / SOUND
- 760 INSPECTION
  - 761 RECEIVING INSPECTION
  - 762 IN-PROCESS INSPECTION
  - 763 ASSEMBLY INSPECTION
  - 764 FINAL INSPECTION
  - 765 SHIPPING INSPECTION
  - 766 FIELD INSPECTION
  - 767 CALIBRATION AND STANDARDS
- 770 TEST ENGINEERING
  - 771 TEST PLANNING
  - 772 TEST REPORTING
  - 773 TEST EQUIPMENT
  - 774 TEST METHODS (DESTRUCTIVE)
  - 775 TEST METHODS (NON-DESTRUCTIVE)
- 780 ENVIRONMENTAL
  - 781 ENVIRONMENTAL CONDITIONS
  - 782 ENVIRONMENTAL EFFECTS
  - 783 ENVIRONMENTAL MEASUREMENT
  - 784 ENVIRONMENTAL EQUIPMENT

800 RELIABILITY
  - 801 DEFINITIONS AND SEMANTICS
  - 802 TEXTS, MANUALS AND HANDBOOKS
- 810 MANAGEMENT OF RELIABILITY FUNCTION
  - 811 ORGANIZATION
  - 812 TRAINING AND INDOCTRINATION PROGRAMS
  - 813 PROGRAM IMPLEMENTATION / EVALUATION
  - 814 VALUE ANALYSIS
  - 815 SPECIFICATIONS / CONTRACTS / REQUIREMENTS
  - 816 PROCUREMENT RELATIONS
  - 817 TRADE-OFF EVALUATIONS
- 820 MATHEMATICAL THEORY OF RELIABILITY
  - 821 PROBABILITY AND PREDICTION THEORY
  - 822 RELIABILITY DISTRIBUTION FUNCTIONS
  - 823 LIFE TESTING THEORY
  - 824 ESTIMATING AND ASSESSMENT
  - 825 APPORTIONMENT
- 830 DESIGN
  - 831 SYSTEM RELIABILITY ANALYSIS / EVALUATION
  - 832 HUMAN ENGINEERING
  - 833 PART SELECTION, ANALYSIS, STANDARDIZATION AND DERATING
  - 834 MAINTENANCE ENGINEERING (SEE 870)
  - 835 CONFIGURATION, PACKAGING STANDARDIZATION
  - 836 DESIGN REVIEWS
  - 837 TOLERANCE ANALYSIS / SAFETY MARGINS
  - 838 DESIGN REDUNDANCY
- 840 METHODS OF RELIABILITY ANALYSIS
  - 841 DATA COLLECTION
  - 842 DATA REDUCTION
  - 843 DATA PROCESSING
  - 844 FAILURE MODES / MECHANISMS / ANALYSIS
  - 845 DATA EXCHANGE SYSTEMS
  - 846 DATA USAGE (PREDICTION, SPARES, ETC.)
- 850 DEMONSTRATION / MEASUREMENT
  - 851 TESTING METHODS
  - 852 USAGE
  - 853 REPORTING, ANALYSIS AND EVALUATION
- 860 FIELD / CONSUMER ACTIVITY
  - 861 TRAINING AND OPERATIONS
  - 862 MAINTENANCE
  - 863 LOGISTICS
  - 864 REPORTING / FEEDBACK
- 870 MAINTAINABILITY
  - 871 MANAGEMENT
  - 872 THEORY
  - 873 DESIGN
  - 874 REPORTING, ANALYSIS AND EVALUATION
  - 875 DEMONSTRATION
  - 876 REPORTING / FOLLOW-UP
- 880 AVAILABILITY
  - 881 MANAGEMENT
  - 882 THEORY
  - 883 DESIGN
  - 884 REPORTING, ANALYSIS AND EVALUATION
  - 885 DEMONSTRATION

(AS REVISED JANUARY, 1963)

INDEX OF SERIAL NUMBERS BY CODES

Serial Number 1306 -1
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A silicon-glass sealed microminiature logic diode

AUTHORS: John H. Forster, Bell Telephone Laboratories, Inc., Allentown, Pennsylvania and Ian M. Mackintosh, Westinghouse Research Laboratories, Pittsburgh, Pennsylvania

SOURCE: solid/state/design, vol. 5, March, 1964, pp. 19-21

PURPOSE: To assess the potential reliability of the pinhead diode.

ABSTRACT: The pinhead diode is a diffused mesa diode which differs from conventional diodes only in its method of encapsulation. The pinhead construction consists of the etched mesa diode, a glass washer which surrounds the mesa, and a heavily doped silicon cap which rests on top of the glass ring. The cap also has a large-area mesa etched on the side touching the glass ring. The purpose of this mesa which contains no junction is to make contact with the much smaller mesa on the other side of the glass ring, which does contain a junction. Encapsulation is achieved by heating the entire sandwich to 800°C, forming a seal between the glass and the silicon.

The electrical performance of the pinhead diode is comparable to that of conventional diodes and its mechanical performance is quite satisfactory. Thermal acceleration curves indicate significant improvement over conventional encapsulations and suggest superior sealing. Heat dissipation is also improved. The size and shape of these diodes make them easy to incorporate into printed and thin-film circuits and they appear to offer an improvement in reliability.

It is pointed out that the thermal acceleration curves serve only to indicate the potential reliability attainable for the sealing process, and that extrapolation of the curves is subject to the usual reservations. A necessary condition for high stability is a good thermal aging characteristic. However, there are aging modes more sensitive to bias aging conditions, and a complete aging program on pinheads is in progress. (They still look better than conventional units in these tests.) Thus at present improved reliability is indicated by the thermal tests, but only within the limitations of such tests.

REVIEW: The diode encapsulation described in this article sounds both simple and economical. The elimination of the conventional package and leads results in an assembly which must in fact look like the head of a pin. Handling losses by the inexperienced user may run quite high, due to misplacement alone.

Figure 1 of the text, showing a photograph of the pieces and their

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

assembly, is something of a puzzle at first glance but the accompanying text and Figure 2 explain the structure adequately. In addition to the appealing efficient use of materials, the diode's electrical performance both before and after accelerated thermal stress substantiates the authors' prediction that the high temperatures employed during sealing create desirable internal "conditions" surrounding the junction. The seal so formed is evidently capable of maintaining these conditions even under what is severe thermal stress for conventional encapsulations.

Some details of the description of the diode's fabrication leave unanswered questions such as the following. Is contact between the two mesas achieved by gravity or is a pressure needed to force the two silicon pieces together during the hot seal? What is the "conventional" seal-in ambient? What constitutes "adequate precleaning" of pyrex glasses such as 7052? The series resistance of the diode is not mentioned, but presumably is no greater than that of conventionally-encapsulated diodes. The low mass of this hot seal assembly may also possess advantages as a microwave diode package.

The first author, in a private communication, has commented as follows: "The questions raised (above) were not answered specifically in the paper primarily in the interests of simplicity, since there are many processing details involved and opinions of which of these are the most important vary widely. For the record, the "conventional" ambient term was used to avoid reference to particular processing ambients. The "conventionals" were selected for their relatively good thermal aging stability. Microwave applications are probably possible, but subject to the dielectric limitations of the sealing glass, and the skill with which the discrete diode can be matched into the waveguide or stripline environment." He has also provided the essentials of the third paragraph in the above ABSTRACT, with a view to emphasizing appropriate words of caution regarding thermal aging.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1307
Code 835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Ceramic substrate improves microcircuit reliability

AUTHOR: (Editorial Matter)

SOURCE: Electronics, vol. 36, November 22, 1963, p. 51

PURPOSE: To report on Amphenol-Borg's program to develop a ceramic substrate for thin-film microcircuits.

ABSTRACT: As a solution to the interconnection problems posed by thin-film microelectronic circuits, ceramic substrates have been developed which permit one-process deposition of elements, interconnections, and conductive paths to outside connectors. To accomplish the latter, channels have been cut in the ceramic substrate and are coated with gold or nickel (as part of the same process cycle as the thin-film circuit deposition).

The substrates are molded from an aluminum oxide compound and possess a vitrified surface comparable to that of conventional glasses. Typical dimensions are 2 x 2 x 0.03 inches, which can be held to a tolerance of 0.001 inch.

REVIEW: This paper is addressed to the problems of packaging and interconnecting thin-film circuit elements. The proposed use of a ceramic substrate is not a new solution, although the specific shape and form described here are probably unique. The advantages claimed for this design can probably be realized with other shapes tailored for other processes. The suggested substrate bespeaks good sensible engineering rather than revolutionary discovery.

The directness with which contact to the outside world is made is striking but may be deceptive in that the process details are not discussed. Throughout the discussion the distinction between what has been done and what, hopefully, can be done is not always clear. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1308
Codes 720;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Control of 3-D weld schedule parameters

AUTHOR: F. C. Fichter, General Dynamics/Pomona, Pomona, California

SOURCE: Electronic Production, vol. 4, March-April, 1964, pp. 14-17

PURPOSE: To describe the weld parameters which must be controlled.

ABSTRACT: The size and shape of the electrodes are determined by the job to be done -- they are usually as large as the job will permit. Once selected they must stay the same. The weld energy and pressure (actually the force) must be selected. The force is set at one of two values (8 or 12 lb.) and is not considered critical. The optimum energy is determined by making welds at different energies, noting their strengths, methods of failure and variability. These are plotted and an optimum value is selected such that small deviations from these conditions do not deteriorate the weld strength. The optimum welds are examined metallurgically for good welding characteristics. The minimum strength can be estimated from a number of pulls; the exact statistics depend on the result desired. The process is continually monitored to make sure it stays in control.

REVIEW: This is a fairly standard treatment of resistance welding for small electronic parts. Some groups prefer to plot isostrength diagrams in the weld "pressure," energy plane. The combination of 3σ, 99.7% failures and nonparameteric statistics is confused but it is not critical to the discussion. Actually, the 3σ has nothing to do with the example at all since a Gaussian distribution is not assumed.

Other papers concerned directly or indirectly with reliability in the welding process have been covered by Abstracts and Reviews Serial Numbers 278, 315, 365, 522, 777, 864, 1144, and 1178. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1309
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relay Facts: Crystal can "logic" -- a most serious matter

AUTHOR: E. U. Thomas, Staff Columnist

SOURCE: Electromechanical Design, vol. 8, March, 1964, pp. 20-21

PURPOSE: To point out problems in the application of crystal-can relays.

ABSTRACTL The crystal-can relay is often seriously misused. This contributes to equipment failures and personnel danger. When switching 115 volts, the can should be grounded for safety, but then there is a chance the relay may arc to the case when breaking. The arc may not occur often in laboratory tests, but it does happen. The 115 v ac rating should be 1/2 amp with no overload allowed. These relays should not be used for simple motor reversing while running, nor should the contacts be placed in the neutral wire.

REVIEW: Relay Facts is a regular monthly column and is worthwhile reading for designers. It discusses proper application and specifications of relays. This month's article makes an excellent point on crystal-can relays. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1310
Codes 775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Circuit failure analysis by potential mapping

AUTHOR: (Editorial Matter)

SOURCE: Electronic Equipment Engineering, vol. 11, October, 1963, pp. 22-23

PURPOSE: To describe the use of a scanning electron probe as an analytic tool for diagnosing integrated circuit failures.

ABSTRACT: A scanning electron probe can be used to take secondary emission photographs of an integrated circuit in operation. By comparing the potential map of a satisfactory unit with that of an unsatisfactory unit, faulty operation can be spotted immediately and often the defect can be pinpointed without mechanical probing, which is itself frequently a cause of more damage. Two secondary-emission photographs are included to illustrate the technique.

REVIEW: This article is extremely brief but states and illustrates clearly the power of a scanning electron probe in detecting causes of failure in integrated circuits. The ability to construct a potential map of an operating circuit is a "breakthrough" not only in failure analysis but in integrated circuit design as well. Of the various uses reported for the scanning electron beam, the secondary-electron photographs, as discussed here and elsewhere (see REFERENCES), could well be the most significant. This particular paper, however, is merely an announcement rather than a complete discussion; accordingly it is of value only to the reader who is learning of this technique for the first time.

REFERENCES:

[1] I. M. Mackintosh, "Application of high resolution electron beams to solid state devices," Abstract No. 118, J. Electrochem. Soc. 110, August, 1963, p. 183C

[2] T. E. Everhart, O. C. Wells, and R. K. Matta, "Evaluation of passivated integrated circuits using the scanning electron microscope," Abstract No. 119, J. Electrochem. Soc. 110, August, 1963, p. 183C

[3] T. E. Everhart et al., "A novel method of nondestructive semiconductor device measurements," paper presented at the 1963 Electron Devices Meeting, Washington, D. C., October 31-November 1, 1963

[4] "Material processing and phenomena investigations for functional electronic blocks," Westinghouse Research Laboratories, Interim Engineering Reports 1-4, Contract No. AF33(657)-9897, Pittsburgh, Pennsylvania, 1962-1963 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1311 -1
Codes 833;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Power transistor safe operating areas

AUTHORS: Richard F. Morey and Henry L. Hardway, Clevite Transistor, Waltham, Massachusetts

SOURCE: solid/state/design, vol. 4, July, 1963, pp. 10, 12, 13, 14

PURPOSE: To describe recent findings on safe operating areas for power transistors used in switching current to inductive loads.

ABSTRACT: The major problem encountered in transistor switching of inductive loads is the high transient voltage produced by current interruption in the inductor. In general, these transient voltages are large enough to drive the transistor into its breakdown region and the amount of power that the transistor is allowed to dissipate must be carefully controlled if an emitter-to-collector short-circuit failure is to be avoided. Two approaches are generally used to limit the dissipated energy to its maximum allowable value, viz. (1) diode clamping and (2) design procedures that limit the maximum energy dissipated during the switching interval to a safe level. The second method is explored in this paper and experimental evidence shows that the maximum allowable energy dissipation during the switching interval is a function of two parameters defined as follows:

V_o = the collector-to-emitter breakdown voltage under the condition of rated current flow, and

$I_{B\ off}$ = the reverse bias current flowing in the emitter-base diode during the switching interval.

The dependence of the maximum energy dissipation on V_o is not surprising since the switching problem arises only when the energy in the inductor is sufficient to drive the transistor into its breakdown region. The effect of reverse bias current is more subtle and is the result of the "pinch effect." As the value of $I_{B\ off}$ is increased, the effective junction area is decreased and current densities within the transistor are increased, leading to strongly localized heating and permanent damage of the transistor.

For a given bias arrangement and a fixed inductive load, the energy that a transistor <u>must</u> dissipate during the switching interval is given approximately by

$$\text{Energy} = V_{cc}^2\ [\tau + 3L/R_L]/6R_L, \quad (1)$$

where V_{cc} = collector-to-emitter bias voltage,

τ = length of the switching interval in seconds,

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

L = value of inductance in series with the collector,
and R_L = total dc resistance in series with the collector.

Equation (1) may be used to obtain a plot of maximum allowable energy dissipation versus $I_{B\ off}$ by fixing a value of $I_{B\ off}$ and then measuring the value of inductance that will just drive the transistor to its breakdown voltage V_o at the instant of switching. The corresponding value of τ is also measured and the energy is then calculated. By using this and other formulas in the text, the maximum permissible inductance can be calculated. As indicated by the above procedure, the experimental evidence shows that the maximum energy that may be dissipated by the transistor during the switching interval is independent of the collector current I_o.

REVIEW: The ideas presented in this paper are correct; however, the exposition generally lacks clarity and there are some typographical errors. The following corrections should be made.

(1) Figure 4 and Graph 3 of the paper are typical breakdown characteristics, not typical collector family curves.

(2) The switching interval, τ, is not marked on Figure 5 and τ is not explicitly defined.

(3) The symbol τ in the upper limit of the third integral of Equation (1) in the paper should be replaced by zero.

(4) The symbol T in Equation (2a) in the paper should be replaced by τ.

Insufficient explanation is given for the "pinch effect"; a reference on this would be helpful. It is indicated that additional information on the ideas presented in this paper may be obtained from the authors. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A worst-case design procedure for resistor transistor logic NOR and NAND gates

AUTHORS: J. A. Hiltebeitel and P. G. Thomas, Lansdale Division, Philco Corporation, Lansdale, Pennsylvania

SOURCE: solid/state/design, vol. 4, July, 1963, pp. 39-46

PURPOSE: To present a DC design procedure for resistor transistor logic (RTL) gates, based on a worst-case analysis.

ABSTRACT: The primary advantages of resistor transistor logic (RTL) are low cost and simplicity. The low cost is achieved by using high tolerance resistors ($\pm$ 10%) to perform the gating function; they replace the more expensive solid state components used in other logic forms. The chief disadvantages of RTL are relatively slow speed and high power consumption. Also, the transient response and propagation time will vary from stage to stage and from time to time during a logic cycle, due to the dependence of available drive current on the number of grounded fan-ins.

A single stage of the logic block is considered and the necessary DC current inequalities to insure the "on" and "off" states are expressed in terms of the stage voltages and resistances. The worst-case philosophy is inserted here by choosing the values (i.e. minimum or maximum) that will be most deleterious to the successful operation of the stage. The resulting expressions include the possibility of having collector clamping and a base turn-off supply. Special cases may be obtained by removing either or both of these effects.

For a fixed fan-in, optimum value expressions for base resistance (R_B), fan resistors (R_K), and fan-out (N) may be obtained for two conditions, viz. (1) optimized resistances with zero tolerances, and (2) realizable resistances with non-zero tolerances. The results of condition (1) yield a measure of the ultimate capabilities of the transistor specifications. A trade-off is observed between the number of fan-outs and the number of fan-ins. The more useful results of condition (2) are given for the following designs:

I. Unclamped collectors--with turn-off supply
II. Unclamped collectors--without turn-off supply
III. Clamped collector--with turn-off supply
IV. Clamped collector--without turn-off supply.

A "current hogging" factor is introduced to account for the variation in fan-out currents due to the variations of R_K and $V_{BE(on)}$ of the fan-out stages. The results of the analysis are all given in the text. Nine references applicable to the discussion are cited.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

REVIEW: This is an excellent worst-case design procedure for RTL circuitry. The development is accurate and complete. Some good illustrations are given, which emphasize the authors' techniques.

The limitations on worst-case design are not discussed here. Before using it, these limitations should be explored.

(On page 42 in the paper, the subheading "Case II" in the right-hand column should read "Case III".) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1313
Code 775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Infrared bond defect detection system

AUTHORS: O. R. Gericke and P. E. J. Vogel, U. S. Army Materials Research Agency, Watertown Arsenal, Watertown, Massachusetts

SOURCE: Materials Evaluation (formerly Nondestructive Testing), vol. 22, pp. 65-68, February, 1964

PURPOSE: To describe an infrared system for detecting defects in bonding one material to another.

ABSTRACT: This paper is concerned with an infrared method of inspecting bond integrity in laminates of dissimilar materials. The method depends on the fact that heat transfer across a defective bond is more difficult than across a good one. Thus, depending on the direction of heat flow, the surface above a good bond will be hotter or colder than that above a bad one. The paper describes the means of heating the object and of sensing its surface temperature. If there are three layers, this method can detect a failure in either bond. If the material is heated from the outside and then allowed to cool, the reversal in sign of temperature difference from good to bad is informative and interesting.

REVIEW: Any non-destructive test which can measure a property beforehand is a good idea, especially when this property can be related to performance at some later time. This paper is a good example of the progress being made in finding new things to measure and new ways of measuring them. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1314
Code 775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An electronic ear for certifying reliability

AUTHORS: R. F. Spain, N. W. Schubring, and M. J. Diamond, Research Laboratories, General Motors Corporation, Warren, Michigan

SOURCE: Materials Evaluation (formerly Nondestructive Testing), vol. 22, pp. 113-117, 128, March, 1964

PURPOSE: To describe a system for acoustically detecting the soundness of metallic castings.

ABSTRACT: When a casting is struck, it will ring. The initial signal is complex, but as it decays, a few tones will persist. These few tones will also decay in amplitude. Both the frequency of the persistent tones and their decay constants can be measured electronically. Good and bad castings are checked to find acceptable limits; then the process can be used for checking part quality. For exploratory work, the piece can be excited by the output of a swept oscillator.

REVIEW: This is a general article to give an idea of what the system can do and how it works. Much of the quantitative work on this kind of test has been done by General Motors Corporation. The technique is difficult to use unless much care is exercised--it is not something that the untrained technician can apply readily.

The quality control technique described here can be used to improve the reliability of metallic castings and should be looked into by anyone concerned with the problem. This article is a good place to start. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1315
Codes 711;713

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Comparing the cast irons and steels

AUTHORS: John F. Wallace and Laurence Leonard, Case Institute of Technology, Cleveland, Ohio

SOURCE: Machine Design, vol. 36, March 12, 1964, pp. 169-200

PURPOSE: To present a comprehensive, property-by-property analysis of the cast ferrous metals -- across-the-board comparisons and recommendations for specifying these important materials.

ABSTRACT: The materials considered are the following.

- Gray Iron
- White Iron
- High-Alloy Irons
  - Wear Resistant
  - Heat Resistant
  - Corrosion Resistant
- Ductile Irons
- High-Alloy Ductile Iron (Austenitic)
- Malleable Irons
  - Standard
  - Pearlitic
- Carbon Steels
  - Low Carbon
  - Medium Carbon
  - High Carbon
- Low-Alloy Steels
- High-Alloy Resistant
  - Heat Resistant
  - Corrosion Resistant
  - Wear Resistant

The properties considered are STRENGTH: Tensile Strength (by which the materials are usually graded), Stress-Strain Behavior, Ductility, Compression, Bending, Torsion and Shear, Fatigue, and Impact; WEAR; DAMPING; TEMPERATURE; CORROSION; EASE OF CASTING AND FABRICATION: Tolerances, Machinability, Weldability; HEAT TREATMENT: Stress Relief, Annealing, Normalizing, Quenching, and Tempering. The metallurgical structure is shown and described for each material.

REVIEW: This is a good summary article and will be useful for choosing a material where the occasion does not allow extensive research. The variability of strength properties from specimen to specimen is not covered, although in many cases ranges are shown for the broad class of materials. The lack is especially noticeable in fatigue (endurance limit). The creep-strength is not shown for all materials. The section on corrosion is rather short. Those engineers who just need a passing familiarity with the properties of ferrous castings will find this article especially helpful. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1316
Codes 351;816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Customer-vendor teamwork leads to reliability gains

AUTHOR: W. P. Koth, Automotive Division, A. O. Smith Corporation

SOURCE: SAE Journal, vol. 71, December, 1963, p. 35

PURPOSE: To explain that a manufacturer should work closely with his part suppliers.

ABSTRACT: Reliability must be designed into equipment and the vendor's help is needed. His parts must be properly applied and he must control their properties. In order to exercise this control and to improve the parts, he should have access to field reports. Proper field experience reporting is difficult but essential.

REVIEW: This is a short one-column article with a good, though not new, message. The author, in a private communication, has indicated that the article was intended as an abstract of a technical session at an SAE Convention held in Milwaukee, but was not printed as such. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1317
Codes 760;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Upgrading the procurement specification

AUTHOR: D. Ekings, Burndy Corporation, Norwalk, Connecticut

SOURCE: Electronic Evaluation & Procurement, vol. 4, January, 1964, pp. 24-26

PURPOSE: To show how to integrate reliability properly into a procurement specification.

ABSTRACT: A buyer must know how to assure delivery of a reliable product at a reasonable cost. Good reliability specifications will aid this process. Reliability and capability are distinguished: capability is related to performance at time zero relative to specified criteria; reliability concerns itself with the ability of good equipment to continue to function in use. Parts should be used within their ratings to help assure long life. Ordinarily, routine acceptance testing and/or requalification are used to check a product's acceptability.

Performing the initial qualification followed by lot to lot acceptance testing, initiating the reliability testing during the qualification phase, and then carrying it through production, avoids restricting delivery. Data can be generated for purposes of a reliability evaluation without penalizing delivery by using such techniques as serialization or lot control.

A basic shortcoming of the usual tests is that they measure on a "go -- no go" basis, but do not tell the actual "strength" of the part. Much good reliability information can be obtained by measuring the "strengths" of a sample and from them, estimating the actual "strength" distribution; many estimates involve the Gaussian distribution. (This is briefly explained.) Demonstrating a given level of reliability can be expensive and should be planned for. Techniques are available to help reduce costs. (An example of reliability criteria applied to connectors is given.)

REVIEW: This is a general article directed toward purchasing agents and does its intended job well. While the purchasing department need not have the understanding in depth of the various concepts, it should have access to them. Otherwise there may be blind slavish following of rules-of-thumb, rather than intelligent application of known principles. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1318
Codes 813;814;817

343;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Right-priced reliability

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement, vol. 4, February, 1964, pp. 22-24

This is an editorial summary of two papers presented at the Tenth National Symposium on Reliability and Quality Control. The papers were covered respectively by Abstracts and Reviews Serial Numbers 1271 and 1200. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1319
Codes 816;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating guide: Buying fixed resistors

AUTHOR: (Editorial Matter)

SOURCE: Electronic Evaluation & Procurement, vol. 4, February, 1964, pp. 27-32

PURPOSE: To show how/how not to select resistors.

ABSTRACT: The material in this paper is organized under the following headings:

Buying Habits are Changing
What's Available
*Mistakes Buyers Are Making
*Failure Mechanisms to Look For
*Approaches to Obtaining Quality
*Value of Published Failure Rates
About Molding Techniques and Encapsulants

This abstract is concerned only with the items marked *, which have reliability connotations.

Buyers should not specify more reliability documentation than they must have; it is expensive.

Resistors fail by opens, shorts, and drift. Look for mechanical defects which might lead to failure, such as poor terminal strength and porous coatings. Be sure the method of putting the resistor in the circuit does not reduce its potential life. Check the proper tests for the particular kind of resistor you are using.

Burn-in tests are valuable for eliminating early failures. Excessive current noise may help screen bad tin-oxide resistors. Problems arise in deciding on the exact tests and limits.

The value of published failure rates is questionable at best. Before they are used, their background should be carefully checked.

REVIEW: This is a rather general article and is slanted toward purchasing requirements. The points made are generally good and will be of value to those who need a quick look at the problem. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1320
Codes 835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating pc board interconnections

AUTHOR: Edward B. Burstein, Westinghouse Defense and Space Center, Baltimore, Maryland

SOURCE: Electronic Evaluation & Procurement, vol. 4, March, 1964, pp. 23-24

PURPOSE: To present the results of an evaluation program on interconnections between both sides of printed circuit boards.

ABSTRACT: Tests were conducted on G-10 copper-clad epoxy-glass laminate, 1/16 inch thick. While the results are not considered final, the following conclusions were reached.

There is no interconnection that is superior in all respects tested.

Eyeletted boards showed the least damage during repair.

Plated-thru-hole boards showed the smallest number of failures during environmental tests.

Mechanically inserted eyelets should not be used as interconnections on double-sided boards unless special techniques are used on the topside of the board to insure a good solder joint.

Bare holes should not be used because of soldering difficulties.

Fused eyeletted boards showed up very well in the repairability and thermal shock tests and appear to be a reliable method of interconnection. (Author in part)

REVIEW: This type of test is very useful for determining failure modes and mechanisms. The results are helpful in determining what manufacturing procedures to use. Publication of results for more of these tests should be encouraged. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1321 -1
Codes 770;813;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor evaluation program

AUTHOR: J. Hilman, Fairchild Semiconductor Corporation

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 81-97

PURPOSE: To outline the plan and report on preliminary implementation of an "extensive device-reliability improvement program."

ABSTRACT: This program investigates the time dependence of the failure rate of the 2N697 and the 2N1613 transistors upon temperature, collector-base voltage, and power dissipation. The ranges considered were: temperature: 25 to 300°C, collector-base voltage: 0 to 80 v, and power dissipation: 0 to 900 mw. Measurements were taken at thirty-eight different combinations of temperature, voltage, and power with a minimum sample size of 100 transistors for each combination (cell). The parameters used to evaluate the transistor performance were:

1. I_{CBO}, leakage current at 30 volts.
2. $1 + h_{FE}$, current gain with base current at 2 ma and collector voltage of 10 volts, and
3. $V_{BE(SAT)}$, base to emitter saturation voltage with base current of 15 ma and collector current of 150 ma.

Data were recorded using automatic test sets which printed and punched the information onto standard punch cards. The measurement repeatability which is considered reasonable with the automatic test sets is on leakage current, $\pm$ (2% + 2 nanoamp); on current gain, $\pm$ 3%; on base to emitter saturation voltage, $\pm$ 2%. Data are displayed as a statistical history of a cell for each parameter, a listing of partial and complete failures in each cell, and a table of failure rates. The overall failure rate for the 2N697 was 0.48%/1000 hours; for the 2N1613 (a planar type), 0.056%/1000 hours.

REVIEW: The instrumentation and techniques used in assembling and presenting the data are quite impressive. The conditions under which the measurements were made are well defined, and the procedures followed are clear and seem complete. The capability of the equipment is excellent. Special coatings (composition not specified) were needed to protect the printed circuit wiring on the test boards from atmospheric contamination and handling, even though the testers wore gloves.

The promise of a unique program given in the opening sentence is never quite fulfilled. By hinting at much loftier aims than just

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

the empirical determination of failure rates, the author seems to suggest here and later on that the goal of this study is to model transistor parameter drift in terms of the environmental variables and time. No progress toward that goal is evident and no details of the course to be followed are revealed. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1322 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of silicon transistors and diodes

AUTHORS: L. E. Miller and I. M. Mackintosh, Bell Telephone Laboratories, Incorporated

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 98-111

PURPOSE: To discuss some typical failure mechanisms in silicon transistors and diodes and the corresponding preventive measures.

ABSTRACT: Failure mechanisms for semiconductor devices can be divided arbitrarily into four broad categories: mechanical failures, electrical failures, failures attributable to materials, and those resulting from ambient effects. The basic precept in designing for reliability is a thorough understanding of the possible modes of failure and an avoidance of situations which might lead to such failures.

Mechanical failure mechanisms, though normally obvious and easily analyzed, are often among the most difficult to eradicate. One example of mechanical failure is that of cracks in glass seals which can result from poor tolerance of parts, rough handling, or from a mismatch between the thermal expansivities of the piece parts. Such cracks often nucleate at minute incipient cracks and propagate under thermal or mechanical stress, finally resulting in a leaky seal.

Most electrical failures result from electrical abuse. Two examples of electrical failure are lead-wire burn-out and device deterioration caused by electrical transients in excess of the device ratings. Lead wires in high frequency transistors are necessarily quite small in diameter because the active region of the device is itself very small. Small nicks or imperfections in these wires can cause localized heating and melting.

Many of the failure mechanisms which are related to materials and/or ambient factors are difficult to analyze. These failures arise out of the basic limitations of the semiconductor and other materials used, and from the environmental capabilities desired of the device. High temperatures and wide temperature excursions present particularly severe materials problems. Oxidation, the presence of minute quantities of water vapor, and the presence of microscopic particles which are inadvertently enclosed in the device encapsulation contribute to poor reliability. Controlled atmospheres within the device case and assembly in clean rooms are examples of measures usually employed to promote reliability. Particularly in the area of materials, considerable

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

progress has recently been made which now enables the device engineer to adopt a less empirical approach to the design of reliable devices.

REVIEW: This paper is well written and should be both interesting and informative to the semiconductor user. Specific examples of a variety of types of failure of silicon transistors and diodes are used to provide a degree of insight into the factors which determine the reliability of these semiconductor devices. The material presented is varied and somewhat limited in detail, in keeping with the survey nature of the paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1323 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability aspects of a grown diffused silicon transistor

AUTHOR: V. Sielewicz, General Electric Company

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 112-126

PURPOSE: To present the results of a transistor life test and interpretation program on a particular family of silicon transistors.

ABSTRACT: The evidence collected to date supports the basic assumption that silicon devices are long-life circuit elements, but it is also known that the individual specimen, whether silicon or germanium, may become inoperative while in normal use, or there may be appreciable drift in major electrical characteristic during life. From the evidence obtained from various life tests conducted on Types 2N332 to 2N336 silicon NPN transistors and presented in this paper, it is possible to divide failures into three main categories: (1) early failures, (2) constant "random" failures, and (3) degradation failures.

Early failures occur during the early period of transistor life, and are considered to be the result of mechanical weakness introduced by the mass production process, and unstable surface conditions of the device itself. Such early failures are weeded out by the application of high-temperature and high-power stresses to the transistor before shipment.

Constant "random" failures are attributed to housing or seal leaks, thermal fatigue, and device surface conditions. Power cycling, i.e., transistor on 50 minutes and off 10 minutes of every hour, induces thermal cycling, and appears to be more effective in exposing latent weaknesses of the transistor than high-temperature storage tests. Thermal cycling will tend to fatigue compression seals, will reveal loose bonds or poor welds, and by establishing thermal gradients, will accelerate migration of any impurities trapped inside the enclosure.

Degradation failures are the result of slow degradation of parameters such as I_{CBO} and h_{FE}, and are attributed to ionized contaminants and moisture trapped inside the housing. High-temperature storage and cycling life tests appear to be reasonably effective in producing this kind of failure.

A number of 2N332 and 2N337 transistors were subjected to the following mechanical environments which were similar to those described in Military Specification MIL-S-19500B: (1) random drop

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

on a maple block, (2) drop shock, (3) centrifuge, (4) vibration fatigue, and (5) vibration at high acceleration. The following types were among the few failures which occurred: (1) excessively high I_{CBO}, (2) decrease in h_{fe}, and (3) loose base lead.

REVIEW: This paper consists primarily of the presentation of data collected during some rather extensive life tests. Because of the rapidly advancing state-of-the-art, papers reflecting that state-of-the-art in any area of this technology, e.g. life tests and their interpretation, rapidly become dated. However, this particular paper remains quite informative and, while attention is focused primarily on one specific type of transistor, the discussion therein provides a general insight into some of the problems of semiconductor reliability. The author, in a private communication, has indicated that since this paper was written a major reliability improvement has been made on this product under the auspices of Autonetics Contract No. A9Q65X-510072.

The term "random failure" has implications which can be misleading. For a discussion of this point see Review Serial Number 1216.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1324
Codes 770;813;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure modes in transistors

AUTHOR: Francis J. Aubin, Jr., Airborne Instruments Laboratory, A Division of Cutler-Hammer, Incorporated

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 127-133

PURPOSE: To review the objectives, scope, and certain results of a transistor testing program.

ABSTRACT: To facilitate reliability estimates and to attain the high degree of reliability necessary in certain equipment, a parts testing program was undertaken by Airborne Instruments Laboratory. This program consists of three major types of testing: qualification, comparison, and exploratory.

Qualification testing is concerned with determining, where possible, if a part can meet the reliability requirements of a given system. The parts are exposed sequentially to one or more of the environmental stresses of shock, vibration, thermal cycling, humidity exposure, vacuum exposure, and to life testing. Comparison testing is used to select the best part from the several which might be available. The test samples are subjected to successively higher levels of stress in environments deemed likely to cause failure. Exploratory testing is used to study areas in which the parts manufacturers do not normally supply information, e.g. the operation of motors in a vacuum, or the behavior of transistors in a vacuum.

Examples of types of transistor failures which have been noted as a result of this program include failures following vibration stressing and attributed to particles which had flaked off the inside of the transistor case; failures caused by slow diffusion of a bonding material into the silicon bar of a transistor; failures following humidity exposure and attributed to leaky glass-to-metal seals; and failures caused by electrical transients. It was not possible in all instances to determine the specific failure mechanism. Often, however, through cooperation with the manufacturer, the cause of failure was both determined and eliminated.

REVIEW: This paper is a report on certain results of a parts testing program conducted by a transistor user. The paper is well written and particularly informative to readers who themselves might be involved in such testing; but the scope is not such as to make it of general interest to circuit designers or other persons concerned primarily with the application of transistors.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1325
Codes 770;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Creep of dc and low frequency parameters of mesa transistors

AUTHOR: F. F. Roberts, Post Office Research Station, London (England)

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 134-138

PURPOSE: To describe experiments in which the total creep of transistor parameters under operating conditions is measured.

ABSTRACT: An ageing circuit has been developed which is free of series contacts, permitting the measurement of transistor parameters by tee-ed-in connections. In such a circuit non-monotonic creep (creep which is removed by an interruption of power) as well as monotonic creep can be detected. The circuit is arranged to permit the measurement of seven parameters and to follow any measurement by grounding and immediate remeasurement, as confirmation of the presence of non-monotonic creep.

Parameter changes of five silicon mesa transistors (2N715) are illustrated after ageing for 1500 hours at 100°C and 200°C at near maximum collector dissipation.

REVIEW: The emphasis in this paper is on the design of a suitable ageing circuit for the analysis of parameter creep. A satisfactory circuit appears to have been developed but only very limited data are reported; thus an assessment of its importance is not obvious from this information alone. The terms monotonic and non-monotonic are not used in their mathematical sense, but in the way defined in the paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1326
Codes 761;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Results of 100 percent screening of transistors and diodes for an airborne digital computer

AUTHOR: L. G. McPherson, Air Arm Division, Westinghouse Electric Corporation

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 139-152

PURPOSE: To demonstrate the need for better screening of silicon components.

ABSTRACT: Thirty-five thousand silicon diodes and 19,000 silicon transistors were screened by the user to provide high reliability assurance for two airborne digital computers, each requiring 14,600 diodes and 6,900 transistors. The need of 100 percent screening arose from the demand for transistors with certain specifications not defined for catalog items. Suppliers could not perform additional environmental tests beyond MIL-T-19500A, nor select to additional and tighter electrical specifications, without substantially increasing cost and extending delivery dates. Therefore, it was necessary for the purchaser to undertake a screening program.

Incoming devices were aged for 100 hours at temperatures of 125°C or greater and were cycled five times from -12°C or less to 125°C or greater. Measurements were then made on all devices, classifying them according to specifications determined by the performance requirements of the computer. The observed failure rate after 700 hours of computer operation using the screened components was 0.04%/1000 hr for the transistors and 0.01%/1000 hr for the diodes. (Author in part)

REVIEW: From the significant number of units rejected by the screening process, it appears that the added testing performed by the user was worthwhile. No clue is given as to how the particular screening process used was developed, but the performance of the computer constructed from devices so screened is a measure of its effectiveness.

The experience reflected in this paper is of interest not only to semiconductor component users who are well aware of similar case histories, but also to the component manufacturer who, as the author rightfully points out, is the one who is in a position to make such time-consuming, expensive screening methods unnecessary. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1327
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of Type USAF-2N404 transistor at high stress levels

AUTHORS: K. R. DeRemer and R. D. Lohman, Semiconductor and Materials Division, Radio Corporation of America

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 168-173

PURPOSE: To present test data on production lots of the Type USAF-2N404 transistor.

ABSTRACT: This paper presents data obtained at RCA from life, mechanical, and environmental tests made on production lots of the Type USAF-2N404 transistor during the first half of 1960, which are life tested as required by MIL-T-19500/20. Operating life tests produce failure rates substantially higher than those encountered on shelf life. This higher rate is experienced even though the computed operating junction temperature is less than the corresponding shelf temperature. Several factors may be responsible for this difference. The possibilities include the following: (1) Operating life tests produce thermal gradients within the device. (2) Operating life tests produce electric fields which may accelerate ion migration. (3) The equipment used to perform operating life tests is inherently more likely to damage a unit through overload than simple storage. (Authors in part)

REVIEW: This paper is a collection of tables and figures for a specific device. While this information is clear, the authors deduce little of general interest other than the statements given in the ABSTRACT. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1328
Codes 770;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quality performance appraisal of an NPN alloy transistor

AUTHORS: R. F. Welch and D. F. Coyle, Semiconductor Products Department, General Electric Company

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 174-182

PURPOSE: To present in simple terms the results of two years' experience with the general reliability of NPN alloy transistors such as the Type 2N388.

ABSTRACT: All production units of the 2N388 germanium alloy transistor are routinely subjected to an electrical aging cycle and a 24-hour leak test in a pressure bomb at 100 psi. Samples are then selected to undergo the following mechanical and environmental tests: dew point, temperature cycling, pressure bomb, drop shock and lead fatigue. Other samples are selected for life tests such as shelf and oven storage and further cycling tests. Each of these tests is defined and the results obtained over a two-year period show that the failure rate is low, reflecting good transistor design and process control.

REVIEW: The large number of satisfactorily operating transistors that is represented by the graphs of this paper should be reassuring to users of the 2N388. Other readers may find the well-defined testing procedures to be of interest.

The authors acknowledge that in selecting the proper test to be conducted it is necessary to know what kind of information is wanted; but the procedures for developing the "proper" test from that knowledge are not given. The reasons for the selection of the particular tests reported on here are either not given or are discussed only in general terms without detail. The impression is that the particular tests chosen, when not required by a military specification, are largely arbitrary. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1329
Codes 720;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design for reliability of a parametric amplifier diode

AUTHORS: F. R. Keene and H. E. Hughes, Bell Telephone Laboratories, Incorporated

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 183-193

PURPOSE: To discuss the electrical and mechanical design, pertinent processing information, and reliability of the Type 1N3152 (reverse polarity) and the Type 1N3153 (forward polarity) diodes.

ABSTRACT: A reliable, diffused silicon, varactor diode is described which is capable of storage temperatures to 200°C. Designed for 4 picofarads capacitance and less than 2 ohms series resistance, it exhibits cut-off frequencies between 50 and 80 gigacycles. It utilizes a gas-tight encapsulation which, because of its threaded stud, is compatible with strip line (printed circuit) applications. Present accelerated ageing data indicate a mean life of the order of 10^7 hours at 25°C. Present failure rate is approximately 2.5 percent per 1000 hours at 200°C and is decreasing. Environmental tests on the production device using a λ equal to 10 indicate it to be compatible with those requirements of MIL-S-19500B which define a device sufficiently rugged for general military usage. (Authors)

REVIEW: This paper discusses varactor diodes from design, through fabrication and packaging, to electrical evaluation and reliability life tests. Particular emphasis is given to the description of the package which is intricate (compare with the "pinhead" diode; see Abstract and Review Serial Number 1306) but performs well. The results of thermal ageing and step-stress ageing, which primarily test encapsulation, attest to the effectiveness of this package.

The description of the formation of the mesa is inadequate; no impurity levels or distributions are mentioned; the description of the technique for controlling the mesa height is vague. The information given on this phase of the diode's preparation is not sufficient to permit duplication by the reader.

The measurement of diode series resistance is accomplished by a measurement of return loss which is claimed to possess desirable attributes as a production line test. An undefined pre-ageing step is shown to reduce failure rate. How or where the pre-ageing step fits into the manufacturing process is not given. ##

Serial Number 1330
Codes 711;720

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relationship of reliability to etching, washing, and encapsulation processing

AUTHOR: Arnold J. Borofsky, Sylvania Electric Products, Incorporated

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 222-238

PURPOSE: To evaluate the importance of etching, washing, and encapsulating techniques on the stability of germanium alloy transistors.

ABSTRACT: Periodic measurements of collector cutoff current and dc current gain were used to evaluate transistor stability as a function of time at either 100°C storage or 150 mw dissipation. The variables whose influence upon stability was investigated were (1) etch composition and washing efficiency for the NPN units and (2) encapsulating materials and procedures for the PNP units. While the NPN units did reveal a dependence upon etching and washing, the greatest changes in stability were related to variations in the encapsulation of the PNP transistors. The most stable encapsulant was found to be a solution of silicone oil, alundum, and molecular sieve in which the dessicant had been dried at 180°C prior to mixing the solution.

REVIEW: The presentation of the data in this paper does not lead to a clear, convincing conclusion. The number of variables that are controlled and found to influence the measured stability is too large. Each new experimental condition yields a stability behavior different from that of the preceding conditions. The fact that no variation is found to be unimportant tends to imply that the random variables may be as significant as the controlled variables. Since the sample size is never given, the absence of statistical evaluation reinforces these misgivings.

The author concludes that moisture level is an important parameter of long-term stability and attempts to explain his data in terms of water content. At one point he must invoke an anomalous interaction between surface impurities and moisture level to maintain consistency, but even then his interpretation is questionable. He also states that the slow failure of a particular group of NPN devices is indicative of a lower concentration of surface impurities, but the observations suggest only a delaying mechanism rather than a reduction in the magnitude of the surface impurities.

This article does not contribute much to the understanding of surface effects other than a confirmation of their complexity. It is an assortment of data, presented with marginal clarity, and lacking in unity of interpretation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1331
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Marginal check analysis performed on a solid-state computer

AUTHOR: J. J. Emashowski, Federal Systems Division, International Business Machines Corporation

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 239-246

PURPOSE: To describe and discuss a marginal check system for detecting and isolating close operating tolerances of circuits or groups of circuits making up logic functions in a solid-state computer.

ABSTRACT: A solid-state computer was built during 1959 to evaluate semiconductor computer techniques. A well-planned marginal check system was included as one of the major design characteristics of the computer. Marginal checking is herein described as the forced unbalancing of circuits, during the operation of programs, for the purpose of detecting close operating tolerances of circuits which make up logic functions. This forced unbalancing of circuits was effected by applying extraneous voltages varying from 0.3 to 0.6 volts to the bases of selected transistors. These voltages were applied through an 82,000-ohm resistance by using a much higher voltage power supply. Three types of circuits were investigated: flip-flop, pulse, and level circuits.

Twelve marginal check lines which failed below a prescribed excursion were investigated. Significantly, only four of the twelve failures involved transistors. All of the other failures involved either wiring errors, ground rule violations, or some oversight in the logical design of a circuit. Transistor characteristics which were a cause of failure included (1) low beta--10 to 15, (2) low output impedance, and (3) a combination of these characteristics. The experience gained during this program has indicated that marginal checking, if thoroughly developed and integrated during the circuit design phase of a computer, is a useful tool in the detection and localization of computer problems.

REVIEW: The subject of this paper remains a major problem today. The work was done in 1959 and, interestingly, indicated that a major cause of failure or marginal performance was that of wiring errors. This particular computer used discrete circuit components and evidently represented the forefront of the state-of-the-art of solid-state computer design at that time. However, many advances have been made in this area since 1959, e.g. the introduction of integrated circuits, and it is interesting to consider the applicability of the techniques and suggestions of this paper in light of the problems and characteristics presented by these newer developments. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1332 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determining the most probable failure rate by relating life test results and application conditions

AUTHORS: Albert L. Goldsmith and Edward M. Yanis, Missile and Surface Radar Division, Radio Corporation of America

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 247-253

PURPOSE: To present a technique for using the results of accelerated life tests to determine the most probable failure rate for a transistor under various combinations of power dissipation and ambient temperature.

ABSTRACT: The problem considered in this paper is that of using transistor life-test results obtained under accelerated conditions to predict expected failure rates under normal application conditions. Two application factors influencing transistor failure rates are power dissipation and ambient temperature. These factors are under the control of the equipment designer; another influence, not under the control of the equipment designer, is that of the inherent reliability of the device as accomplished by the manufacturer and demonstrated by life tests. Life tests usually involve a large acceleration factor over the expected derated conditions of application. The determination of this acceleration factor enables the establishment of a high degree of correlation between the life-test results and the expectations under derated application conditions.

For the transistors studied, data generated by lot acceptance life tests indicated a failure rate of 1.57%/1000 hr, applicable to maximum stress conditions. Field data on transistors of the same type yielded an estimated failure rate of 0.01%/1000 hr at a power dissipation of 40% of the rated value. These data were plotted on a nomograph described in the paper. An exponential form was assumed for the failure rate as a function of power dissipation and ambient temperature. This equation, representing the life test results and the field results fitted to an exponential form, allowed the plotting of additional contour lines on the nomograph. The contour lines were used to determine the most probable failure rate for the type of transistor considered. Necessary input data for this determination included rated maximum power dissipation, rated maximum ambient temperature, power dissipation under application conditions, and ambient temperature under application conditions. The use of the nomograph in making the determination is indicated.

REVIEW: The key problem in the analysis and interpretation of accelerated

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

life test data is always that of obtaining a valid estimate of the failure rate at desired conditions of normal use. This paper presents one approach to the problem, as applied to a particular type of transistor (identified as DEP-type). The same approach could be used for other devices, given the necessary input data. An important assumption which should be noted carefully is the empirically-determined relationship between power dissipation and ambient temperature. The validity of the results is, of course, dependent on the validity of this assumption. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1333
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability observations based on two billion unit-hours

AUTHOR: George A. Kern, ITT Federal Laboratories Incorporated, Division of ITT Corporation

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 254-264

PURPOSE: To provide detailed information on the types, modes, and incidence of failure of semiconductor devices in a large, fully transistorized digital data processing system.

ABSTRACT: The system considered in this paper consisted of 1.1 million components, about half of which were semiconductor devices -- NPN and PNP alloy-junction transistors, point-contact and gold-bonded germanium diodes, and silicon alloy diodes. Failures of the semiconductor units were tabulated according to time of failure, circuit role, and failure mode. From this information the observed failure rate for transistors was calculated to be 0.0678%/1000 hr and that of the diodes 0.0142%/1000 hr.

REVIEW: The components evaluated in this report are probably obsolete at present, as the author states. The failures described are component failures only. No information is available on how or whether failures of interconnecting paths were taken into account.

No conclusions are drawn as to how to improve device performance and reliability, but it is shown that units performing certain functions of the circuit tend to fail more rapidly than other identical units in a different part of the circuit. An obvious remedy is to alter the system design so as to reduce or redistribute the "stresses" at the vulnerable positions. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductor failures vs. removals

AUTHOR: George W. Milligan, The Martin Company

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 265-278

PURPOSE: To explain the concept of failures vs. removals.

ABSTRACT: This paper presents the results of a two-year data collection activity. The study is concerned with the reliability of semiconductors used in various subsystems of the ESAR Feasibility Model. The data cover more than 13,000 semiconductors observed over more than 100,000,000 operating hours. The failure and removal rate data include detailed information on environmental and electrical operating stresses to provide the user with tools for individual analysis of applicability. Adequate confidence limits (90 percent) are imposed on all rate information. The removal-rate to failure-rate ratio varies from unity to infinity, with 10 to 1,000 being a representative span during the initial months of system operation. (Author)

REVIEW: The wording and writing in this paper are confusing. The specific connotations given to failure rate and to catastrophic failure may not be too useful and have several disadvantages. See Review Serial Number 1216 for a discussion on "random" failures.

The author emphasizes the importance of specifying "detailed information on environmental and electrical operating stresses" so that the user will have a good idea of the relevance to his particular application of the failure data presented in the paper. This information is given but the criterion used to define a failure is: "the part has opened or shorted, on a parameter has changed to a value beyond preassigned limits." No such limits are given for any of the approximately ten devices evaluated.

In summary, the paper is not written well enough for the usefulness of the results to come through. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1335
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Five million unit-hours of power ageing data on diffused silicon diodes

AUTHOR: J. H. Wiley, Jr., Bell Telephone Laboratories, Incorporated

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 279-287

PURPOSE: To study ageing trends, replacement rates and product fluctuations of silicon power diodes.

ABSTRACT: Samples of five vacuum-encapsulated diffused silicon power diodes, selected at random from production lots, have been operated in their normal modes at maximum power ratings for 1000 hours. The five types of diodes examined were (1) 10-watt medium voltage rectifier (10 amps forward current rating), (2) 1-watt medium voltage rectifier (1 amp forward current rating), (3) 1-watt high voltage rectifier (1000-2000 peak inverse voltage), (4) 10-watt regulator diode, and (5) 1-watt regulator diode. Results show that (1) With the same inverse voltage applied during ageing, the 10-ampere rectifier has more early failures than the 1-ampere rectifier. (2) The 1-ampere 250-volt rectifier has fewer early failures than the 500- and 600-volt 1-ampere diodes. (3) The high-voltage rectifiers (1,000 to 2,000 volts), when aged at the same power dissipation as the 1-ampere rectifiers, had no failures. During processing, however, these diodes were baked out at higher temperatures than the other diodes mentioned here. (4) Voltage-regulator diffused silicon diodes of both the 1- and 10-watt designs had approximately one million unit-hours of life testing with no failures. (5) Data to date (1,000 to 10,000 hours) indicate that the failure patterns follow the log-normal distribution quite closely. (Author in part)

REVIEW: This paper clearly and concisely describes a series of evaluation tests. The conclusions as listed in the ABSTRACT above are well founded.

The fact is not surprising that the diodes rated at the higher currents and votages tended to fail more rapidly than similar units with lower ratings. The author makes no comment on this point other than to take note of it.

The test circuit for these maximum power rating tests is of interest. At a 60-cycle rate it switched the unit being tested from a state of maximum rated average forward current to that of rated peak inverse voltage. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1336
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Microdiode reliability evaluation

AUTHORS: E. E. Maiden and W. S. Eckess, Pacific Semiconductors, Incorporated

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 288-300

PURPOSE: To recommend microdiodes as components having superior reliability.

ABSTRACT: In general the term microdiode is used to describe a diode that is at least an order of magnitude smaller in size and weight than its conventional counterpart. The specific structure evaluated here is a passivated diffused silicon diode chip surrounded by a protective coating and from which leads protrude. No can or other encapsulation is used.

The reliability of such microdiodes has been examined by subjecting quantities of them to environmental, high temperature storage, and operational tests. Forward current, reverse current, and saturation voltage were used as measures of performance in these tests. Results, presented as summaries of specific tests, show the microdiodes to be stable units of potentially high reliability.

REVIEW: The chemical composition of the coating used to protect and seal the microdiodes discussed in this paper is not given. A cross-sectional view is shown which gives the appearance of extreme simplicity when contrasted with the varactor diode package pictured in the paper covered by Abstract and Review Serial Number 1329. Surface passivation is not accurately defined and the details of construction are described only in the broadest of terms, presumably to guard proprietary interests.

The testing appears comparatively extensive and, although high humidity environments consistently cause measurable degradation, the total change does not cause catastrophic failure by the author's criterion. (A catastrophic failure is probably a diode with reverse current greater than 100 microamps at a reverse bias of 50 volts, although Table II, which gives the failure criteria, does not explicitly define all these conditions.) In all other tests the units perform quite well in spite of appearing to be rather vulnerable. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1337
Codes 780;833;837;
844;851

833;851;864

422;822;824;
833;844

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

TITLE: Comparison of operating life tests and storage tests

AUTHOR: C. H. Zierdt, Jr., Semiconductor Products Department, General Electric Company

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 153-167

This paper is the same as the one covered by Abstract and Review Serial Number 135.

TITLE: Survey of life test evidence of semiconductor devices in commercial production

AUTHOR: R. Brewer, Research Laboratories, The General Electric Company Limited (England)

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 194-221

This is a more extensive presentation of much the same type of information as that found in the paper covered by Abstract and Review Serial Number 143.

TITLE: Transistor reliability estimated with the Poisson distribution

AUTHOR: C. H. Li, Semiconductor Division, General Instrument Corporation

SOURCE: Semiconductor Reliability, edited by John E. Shwop and Harold J. Sullivan, Engineering Publishers, Elizabeth, New Jersey, 1961, pp. 301-309

This paper is the same as the one covered by Abstract and Review Serial Number 82. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1338
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Introduction (to the Symposium on the Physics of Failure in Electronics, September, 1962)

AUTHOR: Harry Davis, Deputy for Research, Office of the Assistant Secretary (R & D)

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 1-3

PURPOSE: To define the motivation for and the goals of the physics of failure program.

ABSTRACT: Understanding of the mechanisms and physics of failure is the key to the order of magnitude improvements in component life demanded by contemporary electronic systems. Conventional, after the fact statistical testing and reliability assessment is too costly, too time-consuming, and too late. It is also inflexible, being valid only under certain specific conditions.

The physics of failure program holds the promise of (1) furnishing a mathematical model which relates component performance to operating time and stress, (2) providing a method of predicting reliability in advance and independent of any extensive test program, and (3) making reliability information applicable over the complete range of environmental and operational conditions.

REVIEW: This introduction summarizes the interest of the Defense Department in reliability and its hopes for the approach represented by the physics of failure program. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1339
Codes 813;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and the physics of failure program at RADC

AUTHOR: Joseph Vaccaro, Rome Air Development Center, U.S.A.F.

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 4-10

PURPOSE: To state the origin and goals of the physics of failure program at RADC.

ABSTRACT: The demands for more versatile and faster performance from military electronic systems have led to greater system complexity and an inevitable increase in the frequency of system failure. For component parts the consequences are the need for orders of magnitude increases in life expectancy and the immediate availability of valid and versatile reliability data on each component. Tedious statistical processes do not fulfill these needs; the physics of failure approach, identifying part failure with its physical cause, may be the best or perhaps the only answer.

Nine contractors are currently working on various phases of the RADC program with emphasis on the study of the bulk and surface effects on the electrical properties of materials. The overall program goal is the complete determination of the reliability parameters of a component (in advance of any testing) from the knowledge of the physics and chemistry by which it can fail. Two routes are being followed, viz. (1) the detection, identification, and measurement of individual failure mechanisms, and (2) the establishment of a comprehensive mathematical model by which component failure is expressed in terms of individual failure mechanisms.

REVIEW: This paper serves as an excellent introduction to the volume in which it appears. After learning the program philosophy and goals, the seemingly diverse topics of the papers, as represented by their titles, assume a unity not otherwise apparent. This paper is highly recommended as a starting point for the reader who is accustomed to perusing conference proceedings at random.

The program goal as stated is probably incapable of being achieved. An alternative goal is the <u>adequate</u> determination of the reliability parameters of a component from the knowledge of the physics and chemistry by which it can fail and from a minimum of testing. ##

Serial Number 1340
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Physics of resistor failure

AUTHORS: Charles W. Lewis and John J. Bohrer, International Resistance Company, Philadelphia 8, Pennsylvania

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 11-19

PURPOSE: To classify general causes of component failure, to examine some failure mechanisms of metal film resistors, and to make some general observations on the procedures for accelerated testing of components.

ABSTRACT: By viewing component reliability as a study of the mechanisms of change and their retardation rather than a study of stability and its augmentation, the results of accelerated testing can be used to predict performance over a wide range of conditions. Errors arise when the temperature-activated failure mechanisms that are dominant during accelerated tests are different from the mechanisms which actually determine failure under operating conditions. A simple linearity check of a plot of log failure rate vs. 1/T is sufficient to avoid such errors.

Causes of failure can be classified as thermal, corrosive, or radiative, or, again, as either intrinsic or environmental. Observed environmental failure mechanisms for resistors are oxidation and electrolysis.

REVIEW: This paper is a series of loosely connected ideas. The points generally are valid but not original with the exception of the few comments relating to the failure mechanisms observed in metal film and other resistors. An interesting print of the electron diffraction pattern of a chromium film before and after oxidation is noteworthy.

The text is not free of ambiguities and errors. The term "conductance" is used to describe conductivity x thickness whereas a term such as "sheet-conductivity" would be more appropriate. The change in thickness of the resistive film is equated to the thickness of the growing oxide; in general this condition is not true. The decrease in film thickness is proportional to the thickness of the oxide; that is, the constants A and B generally differ in the expression for the oxide thickness and the decreased film sheet-conductivity. In the same development some typographical errors appear and the electron diffraction print referred to previously is upside down. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1341
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Progress report on a study of the primary modes of failure occurring at material interfaces found in thin-film solid state devices

AUTHOR: Kenneth F. Greenough, Solid State Division, Motorola, Inc. (present affiliation: Signetics Corporation, 680 West Maude Avenue, Sunnyvale, California)

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 20-33

PURPOSE: To describe some models and results relevant to failure mechanisms at surfaces and interfaces.

ABSTRACT: This paper considers three model systems: (1) interface between a metal film and a thin-film glass dielectric, (2) interface between a metal film and its anodized surface, and (3) interface between a semiconducting metal oxide resistance element and its substrate. Materials used in the first system are vapor-deposited silicon monoxide and aluminosilicate glass as the dielectric and vacuum evaporated thin-film metal electrodes of Al, Cu, Au, Ag, and Cr. Capacitance and dissipation factor measurements were made on these structures as a function of frequency and environment. These tests were designed to illustrate such phenomena as diffusion and polarization. Tantalum-tantalum oxide-gold units with varying oxide thicknesses were used as test vehicle for the second model system. These units were tested by performing capacitance and dissipation factor measurements as a function of frequency and environment. Optical microscopy was also used in the first two systems to determine such effects as pin-holes and contamination. The test vehicle for the third system was tin oxide, deposited by the vapor phase reaction technique on a variety of substrate materials. Tests were performed to determine the effect on the resistivity of the tin oxide of such parameters as the thermal expansion coefficient, thermal conductivity and surface structure of the substrate material. Measurements of resistivity, temperature coefficient of resistivity, and current noise index were made for various temperatures and dc levels.

REVIEW: This paper describes the results of limited tests performed on the indicated models. The information presented is useful and should add to the growing knowledge of the surface and interface phenomenon. It should be noted that duplication of the present systems may be difficult due to the many parameters involved.

The author, in a private communication, has indicated that a more complete summary of this work has been published as a final report by Rome Air Development Center, "RADC-TDR-63-152, March 1963."

##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1342 -1
Codes 711;714;716;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nonlinear mechanisms and stress concentrations

AUTHORS: Selby M. Skinner and John W. Dzimianski, Westinghouse Electric Corporation, Air Arm Division

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 34-55

PURPOSE: To identify some causes of failure in semiconductor devices.

ABSTRACT: Six independent experiments are described which are representative of the experimental and theoretical work of a specific failure mechanism program. Experiment 1 shows the deleterious effects of electrostatic surface charge upon the static characteristics of a transistor; experiments 2 and 3 are concerned with the operational theory of a stick-slip stylus and show traces of such a stylus crossing the surface of various silicon specimens which contain planar p-n junctions. The stylus is a sensitive tool for measuring surface potential and detecting surface inhomogeneities that might otherwise be unnoticed. Experiments 4 and 5 utilize the photovoltaic effect to measure surface ageing effects and the electrical effects of mechanical stress. Surface ageing is expressed as exposure time to air following a CP-4 etch and is shown to introduce irregular variations into the sign and magnitude of the photo-emf measured on the surfaces of p-type germanium and silicon. The amount of contact pressure on p-type germanium and silicon is also shown to change the sign and/or magnitude of the photo-emf. The final experiment consists of monitoring the electrical and physical deterioration of semiconductor specimens under repetitive mechanical flexure. Such stressing causes "reversible" microcracks and fracture patterns with observable distortion of surface potential during the peaks of maximum stress. The electrical response deteriorates with continued flexing, indicative of irreversible damage.

REVIEW: This paper is a well organized presentation of a series of experiments relating the surface and bulk properties of silicon and germanium devices to their electrical performance. The experiments are relatively basic and reflect the absence of theory adequate to explain the observations.

Various minor errors appear: on page 40 "12 ohms per square" should read "12 ohm-cm"; on page 49, Figure 10, "b = 0.30" should probably be "b = 1.30" to agree with the corresponding text, but even then the time axis in Figure 10 seems to be incorrectly scaled; also on page 49 the word "Si" seems to be incorrect since the discussion preceding it has been about germanium. Figure numbers and captions have been omitted throughout the paper

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

causing, however, only slight inconvenience to the reader.

Experiment 1 confirms the Atalla model [1] of the surface changing under an applied bias. The conclusion that "the nature of the remedial measures to be undertaken by the manufacturer is clear" seems a bit too glib. No such remedial measures are given and the hypothetical example of an assembler electrostatically charging a transistor during encapsulation seems from the information in the paper to be unlikely, since such a unit would be rejected either by the manufacturer or by the first user. In a private communication the authors have indicated that the rejection occurred during the customer's initial screening for a system application (the manufacturer having failed to reject the unit probably because of the sampling methods used). Thus the possibility of charges being acquired during manufacture is reasonable, although the sequence of events preceding rejection is not obvious from the original paper.

The results of the stick-slip stylus measurements, particularly the figure showing the effect of a water spot, are valuable and interesting. This technique, however, seems to offer no advantages over the recently-publicized secondary-electron method (see Abstract and Review Serial Number 1310) and is more destructive, less graphic, and slower. In the private communication mentioned above the authors have commented as follows. "The secondary electron method when applied to the study of microelectronic devices causes them to acquire a high charge (similar to that discussed in experiment 1) which is difficult if not impossible to remove in reasonable periods of time. This does not reduce the value of the method as an investigative tool, per se. The "stick-slip" or CSEP (Contact Scanning Electrical Probe) method has been examined, and it is found that if light pressures are used repeated traces show that the semiconductor surface is unaltered; tests on devices scanned by it show that device performance is not impaired. It is true that the CSEP method is less graphic, but it is also less rather than more destructive."

The angle-lapped portion of the specimen in Figure 6 is not labelled; since the original surface is more prominent, it can easily be mistaken for the angle-lapped region. The stains on the original surface, however, have delineated junctions which are the antithesis of the uniformity claimed by the authors, and only by deduction and further examination of the photo is the reader able to see that the upper portion of the stained region delineates the sub-surface junction topology.

REFERENCE: [1] M. M. Atalla, A. R. Bray, and R. Linder, "Stability of thermally oxidized silicon junctions in wet atmospheres," Proc. Inst. E. E. (London) vol. 106, part B, no. 17, pp. 1130-1137, March, 1960 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1343
Codes 715;782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Anomalous radiation damage effect on capacitance of Si diodes

AUTHORS: R. V. Babcock and P. J. Malinaric, Westinghouse Electric Corporation, Research and Development Laboratories, Radiation and Nucleonics Laboratory, Pittsburgh, Pennsylvania

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 56-67

PURPOSE: To report on a study of the anomalous changes in abrupt junction capacitance of Si diodes with exposure to radiation.

ABSTRACT: Considering the changes in bulk properties of silicon due to irradiation and the models so successfully used to predict the operation of abrupt p-n junctions, a decrease in capacitance might be expected after electron irradiation of silicon charged particle detectors. Ten detectors were simultaneously irradiated with 2 Mev electrons at flux rates from 5×10^{10} to 5×10^{11} electrons/cm^2-sec. Four surface barrier detectors failed immediately due to the sensitivity to electron damage of the supporting structure. The remaining six phosphorus diffused detectors were exposed to an integrated flux in excess of 10^{16} electrons/cm^2. The resistivity of the initial base material was 10^2, 10^3, and 10^4 ohm-cm. Two effects of electron irradiation on detector capacitance were observed: a proportional increase in capacitance at all bias voltages, and a steady increase in capacitance at high bias relative to the low bias values. The increase in capacitance was more rapid as a function of irradiation for the higher resistivity material.

Changes in counting characteristics of these junctions were accompanied by an increase in the reverse leakage current and in the amplitude of the noise. However the detectors were more resistant to electron damage than expected. The rapid increases in leakage currents and noise levels would prevent their use in high resolution applications after integrated fluxes $\sim 10^{15}$ electrons/cm^2. For certain applications the use of low resistivity detectors to integrated fluxes $\sim 5 \times 10^{16}$ electrons/cm^2 is feasible.

REVIEW: Although the authors were unable to resolve the anomaly, attributes of the fundamental mechanisms are identified. Also the data presented are of practical value concerning the changes in counting characteristics of diffused junctions as a result of electron irradiation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1344
Code 813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Project control to provide for the physics of failure in electronics

AUTHOR: Clifford M. Ryerson, Pan Technical Systems, Inc., Montrose, California

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 68-72

PURPOSE: To convince the reader of the desirability of the physics of failure approach to reliability and to recommend methods of securing its adoption.

ABSTRACT: In spite of its soundness, the physics of failure approach to reliability is not the one most commonly used. Quick, inexpensive fixes ("shallow" fixes) involving parts replacements primarily are more popular, even though the physics of failure approach (the deepest of all fixes) may be the least expensive in the long run. Shortsightedness on the part of middle management is responsible for relegating the physics of failure to a secondary role in a project; the military program sponsors are in a position to change this error by requiring the physics of failure approach to be used on all their programs.

REVIEW: The general arguments presented in this paper are unlikely to sway any opinions on the merits of the physics of failure program. To believe these arguments with conviction the reader must already believe the conclusion.

The least controversial points are the practical observations that (1) a benefit of the physics of failure approach is to compel communication between R&D and production engineering, and (2) a reason for not using the physics of failure approach is that few military contracts require it and therefore "military contractual people" are responsible for the program's falling short of the situation which the author considers appropriate, i.e., a 100% physics of failure approach to reliability. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1345
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fundamental failure mechanism studies

AUTHORS: R. G. Phillips, G. P. Anderson, and R. A. Erickson, Univac Division of Sperry Rand Corporation, St. Paul, Minnesota

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 73-90

PURPOSE: To describe a method of component-reliability improvement.

ABSTRACT: Univac's experience in component failure problems has indicated that an effective failure analysis program for a system producer has to be capable of determining if the failure is caused by problems of materials, design, technique, or processes. Failure analysis has a particular responsibility to determine if the failure is indicative of a basic fault in the total population of parts or assemblies, or if it is indicative of a problem causing a small proportion of unreliable parts within an inherently reliable population. The application of failure analysis, feedback of information, and development of screening techniques designed with failure mode information has materially contributed to the achievement of ultra-reliable computer systems. Examples of failure modes on which information has been obtained are the "purple plague" of silicon transistors, brittle contact alloys on germanium transistors, high transistor leakage currents caused by lead arrangement, and other similar problems. Screening techniques have been developed for semiconductor diodes and for welded component leads which materially increase reliability.

REVIEW: An editorial problem which is found in other papers in this publication is very evident in this article. The figures are not numbered and no captions are given although references in the text are to figure numbers. This results in some difficulty in following the discussion. Among the nineteen illustrations are some good micrographs of semiconductor devices illustrating the failure modes being discussed. Both the arguments for component failure mode analysis and for screening are illustrated with good practical examples of their usefulness. A generalization of the two-population hypothesis (the population consists of a large group of reliable parts plus a small but significant group of weak, substandard parts which tend to reduce the reliability of the final product) is worthy of further testing to see if it is, in fact, true. In this circumstance, no amount of hypothesizing will substitute for facts. This is a good readable description of practical methods for component reliability improvement. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1346
Codes 715;782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effects of high energy radiation on failure mechanisms in semiconductor devices

AUTHORS: V. R. Honnold and C. B. Schoch, Hughes Aircraft Company, Fullerton, California

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 99-103

PURPOSE: To report on a study of the usefulness of high energy radiation as a diagnostic tool in the analysis of failure mechanisms.

ABSTRACT: A total of 26 germanium-alloy diodes were subjected to a 1000-hour operating life test at 25°C. Of the 26 diodes, 13 failed at 500 hours due to an increase of reverse current beyond the specification limit. All others passed the test for 1000 hours. In addition, 16 silicon-alloy diodes were subjected to a 1000-hour 200°C storage life test. Of these, 5 failed after 546 hours due to an increase in reverse current outside the specification limit.

These diodes were exposed to Co^{60} radiation. The initial exposure was about 0.5 megaroentgen which did not produce any consistent effect in either the good or failed units. A second exposure brought the total to 1 megaroentgen and resulted in an appreciable decrease in the average forward current and increase in the reverse current for the germanium diodes. Further exposure to 50 megaroentgen resulted in an opposite effect for the forward characteristic of the good diodes and the reverse current of the failed units. The considerable decrease in the reverse leakage current of the failed units suggests a gross effect of the radiation on the failure mechanism. Consistent results were not obtained for the silicon-alloy diodes.

REVIEW: The observation is certainly an interesting radiation effect; however, the association of the decrease in reverse leakage current with the effect of radiation on the failure mechanism is mostly speculative. In this instance it appears that more fundamental and detailed information about the effects of radiation on the specific devices must be obtained before this approach can lead to an understanding of the physics of failure.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1347
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Characteristics of "second breakdown" and transistor failure

AUTHORS: H. A. Schafft and J. C. French, National Bureau of Standards, Washington 25, D. C.

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 104-107

PURPOSE: To describe a transistor failure mechanism called second breakdown and to discuss its origin.

ABSTRACT: "Second breakdown," which is also known as "secondary breakdown," "snapback" and "breakback," is usually characterized in transistors by an abrupt reduction of the voltage between the collector and emitter (V_{CE}) from its normal operating level to a level which can be as low as a few volts and as high as about 25 volts depending on the transistor type and current value.

Every sample of every type of transistor examined that had leads capable of passing the required current could be driven into second breakdown. The transistors examined included both p-n-p and n-p-n polarities on silicon and germanium wafers with a variety of resistivity profiles and structural geometries. The resistivity profiles included those typical of alloy, double diffused and drift transistors. The geometries included the disk-emitter and the ring-emitter as well as mesa, epitaxial and planar structures. It is felt that a sufficient variety of transistor types has been examined to be able to suggest that second breakdown is a more fundamental property of the transistor than has previously been thought. The problem of coping with second breakdown is serious not only because the physics of second breakdown is not fully understood, but also because its characteristics are not fully and widely described. (Authors)

REVIEW: This is a review paper summarizing the observations and interpretations of the second breakdown phenomenon. It is a digest of the authors' previously-reported work [1], which has recently been extended [2].

REFERENCES:

[1] H. A. Schafft and J. C. French, "Second breakdown in transistors," IRE Trans. on Electron Devices, vol. ED-9, pp. 129-136; March, 1962

[2] H. A. Schafft and J. C. French, "Second breakdown; effects of base drive and structural defects," National Bureau of Standards Report 8122 (See Abstract and Review Serial Number 1365) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure physics: an essential discipline for reliability engineering

AUTHORS: David W. Levinson, Metals and Ceramics Division and Robert G. Pohl, Physics Division, Armour Research Foundation

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 108-122

PURPOSE: To advance the thesis that the change in performance of a part with time occurs as the result of natural processes which follow known laws.

ABSTRACT: If one knew the mechanisms by which the important physical properties of a part are affected by the environment well enough to write down the exact relationships, then one could calculate the lifetime of the part under any given condition.

A deposited metal film resistor is affected by changes in the nature and geometry of the film. The processes of oxidation, evaporation, diffusion, and changes in crystalline structure will change the nature of the film and its geometry. General equations for these are written and combined so as to agree with some experimental data on resistivity changes.

REVIEW: The major portion of the paper deals, not with the general subject, but with the specific resistor type. Indeed there is little need for discussion about the main thesis. The real problem and about which there can be considerable controversy, is whether this procedure will ever allow the prediction of characteristics in advance to agree with extensive measurements on produced parts. It is safe to say that this is not possible on anything today and the likelihood of its being possible in the next decade is slight indeed. A more useful objective is to try to gain as much knowledge about the behavior as we reasonably can and to use this to develop better longer-lived parts. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1349
Code 851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Acceleration factor determination and reliability analysis of precision film resistors

AUTHORS: W. E. McLean, J. A. Thornton and H. R. Aschan, Electra Manufacturing Company, Independence, Kansas

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 4-11 (see also Electrical Design News, vol. 8, December, 1963, pp. 78-84, 89-91)

PURPOSE: To show how acceleration factors were determined for a fixed film-resistor life test.

ABSTRACT: Preliminary tests and plan-requirements suggested running resistors at 0.5, 2.5, 5, and 10 times rated power. Resistance deviation was measured as a function of time. Weibull distributions (two-parameter, with the location parameter set = 0) were used to analyze the data. The desired resistance change was not achieved during the test and extrapolation models were created. The final model was used for qualification tests of a carbon film resistor for Minuteman ground environment.

REVIEW: The paper is largely a description of the models that were used to analyze the test data. When models are fitted to data and then evaluated well outside the range of the data (as was done in this paper) it is most advisable to evaluate the uncertainties in the estimates. This can be done by conventional techniques. Unfortunately this type of analysis was not done here and there is an air of precision or accuracy about the resulting acceleration formulas which is undoubtedly not justified. The question of whether the form of the model is suitable for extrapolation is another matter, but the above statement is made granting that the models are adequate.

The implication that the Weibull analysis does not necessitate "... an assumption concerning failure rate characteristics of the units being tested" is not true. It assumes a very special form for the conditional failure rate, namely that implied by the Weibull formula.

While extrapolations are inevitable in good engineering practice, the uncertainties should not be hidden in the mathematics; insofar as possible, they should be uncovered and made explicit. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1350
Codes 520;716;770;
782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aging characteristics of vapor-deposited chromium film resistors

AUTHOR: A. O. Fowler, Components Division, International Business Machines Corporation, Poughkeepsie, New York

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 12-19

PURPOSE: To describe an investigation of the aging characteristics of vapor-deposited, thin-film chromium resistors under various stresses.

ABSTRACT: A sample of 360 resistor networks (vapor-deposited, thin-film, chromium resistors) was tested to determine the effects of temperature, load, humidity, time, and their interactions. The results were subjected to an analysis of variance.

Within the ranges covered in this test, the following stress effects are indicated for resistor networks of this type:

1. High humidity is the greatest contributor to resistor aging. In fact, if the humidity is held consistently low, the levels of temperature and load employed in this test should have minimal effects on the resistors.
2. Pronounced effects due to increasing temperature and significant (but weaker) effects due to increasing load will be encountered if the resistors are subjected to humid environments.

These effects can be attributed to the generally accepted mechanisms of degradation for resistors of this type, where oxidation effects are accelerated by high temperatures and where galvanic effects occur when the resistive elements are exposed to humidity under low-load conditions.

This test was not specifically designed to gather distribution-oriented application information. The data indicate, however, that similar units--if effectively protected against humidity--could be expected to experience average drifts of 1% or less in 10,000 hr when applied within the stress ranges of load and temperature covered and when subjected to typical computer environments. The range of deviations during this time should be -0.5% to 2.0%. (Author in part)

REVIEW: This series of tests appears to have been well planned, well executed, and well analyzed. The engineering and statistical assumptions that were made appear to be well recognized. (The assumptions of additivity of the effects and normality, independence, and common variance of the experimental errors in the analysis of variance are not explicitly stated.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1351 -1
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transients in solid tantalum capacitors

AUTHOR: W. G. Bailey, Cornell-Dubilier Electronics, Division of Federal Pacific Electric Company, Norwood, Massachusetts

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 29-32

PURPOSE: To describe a study of the effects of transients in solid tantalum capacitors.

ABSTRACT: This paper presents the test procedures used, the results obtained, and a discussion of the test results from an investigation of the effects of transients on solid tantalum capacitors.

The solid tantalum capacitor is an electrolytic capacitor employing a sintered tantalum powdered anode of very high surface area. The capacitor dielectric is of electrochemically formed tantalum oxide. The manganese dioxide cathode is formed by the pyrolysis of manganous nitrate.

The operating characteristics of particular interest with regard to transient capabilities are the changes in dissipation factor and dielectric strength at high ambient temperatures. These are important because the capacitors are usually operated in ambients above room temperature. As the capacitor operating temperature increases, the dissipation factor increases. The dielectric strength and the insulation resistance of the dielectric film decreases as the temperature is increased. There is also a possibility of dielectric crystallization under certain voltage and temperature conditions; this may lead to short circuits.

Three arbitrary energy levels were used for the transient pulses in the electrical tests. They are called low, medium and high energy transients. Capacitor discharge equipment was used for the low and medium energy transients, and a high current power supply for the high energy transients. The low and high energy transients tests were conducted at 60 pps, and the medium energy testing was at one pulse every 30 sec, and 1 pps.

The results of these studies show that these capacitors have a rather limited capability to withstand transient pulses, which develop voltages in excess of the surge rating of the capacitor. As the energy and the repetition rate of the transient increases, the capacitor is damaged or fails at lower peak pulse voltages, and a thermal problem may exist.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Recommendations, based on these tests, are made as a guide to the application of solid tantalum capacitors. However, the best method for determining the choice of a capacitor, or any electrical component, for use in a new or unique application is an evaluation of the component under actual operating conditions.

REVIEW: This paper has a strong bearing on the reliability of solid tantalum capacitors. The detailed recommendations should be incorporated in all manufacturers' operating specifications.

The author, in a private communication, has made the following suggestion. "It is possible to put in a resistor in series with the solid tantalum capacitor which will damp the transient pulse to a voltage below the surge voltage rating of the capacitor. The use of this resistor would have to be determined experimentally for a specific circuit application." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1352
Codes 770;782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The determination of failure mechanisms and environmental limits for electronic connections

AUTHOR: W. K. Antle, The Boeing Company, Aero-Space Division, Seattle, Washington

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 56-60

PURPOSE: To describe the methods used and the results obtained in an investigation of the failure mechanisms and environmental limits for certain types of electronic connections.

ABSTRACT: A testing program was devised to evaluate the performance of representative electronic connections under the following environmental extremes: high temperature, mechanical shock or impact, and salt-water corrosion.

The types of connections tested were:

1. Resistance welds of nickel wires crossed at 90°.
2. Crimp connections consisting of rhodium-plated contacts crimped to silver-plated stranded-copper wire.
3. Solder joints using silver-plated stranded-copper wire joined to gold-plated contact cups.
4. Solder joints consisting of solid tinned-copper wire joined to an epoxy-glass printed-circuit board.
5. Wire-wrap joints of solid tinned-copper wire to brass terminals.

The conclusions drawn from high-temperature testing were that solder joints lose mechanical strength rapidly above 200°F; crimp connections depend upon the strength characteristics of the wire itself; welds using nickel wire resist high temperatures better than the other connection types tested.

In the mechanical shock environment the performance of the wire-wrap joints and the welded joints was considerably superior to all of the others, the wire-wrap being slightly superior to the welded joint.

The corrosion tests revealed that only nickel welds are unaffected by the salt solution. Solder joints appear to retain their useful properties even though corrosion takes place.

REVIEW: This is an excellent paper. The investigation was well organized and is reported in a clear concise manner; the results are well worth bearing in mind by anyone concerned with the reliability of electrical connections. ##

Serial Number 1353
Codes 710;720;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Welded electrical joints and criteria for process acceptance

AUTHOR: R. A. Geshner, Defense Electronic Products Division, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 61-66

PURPOSE: To show how to determine acceptable ranges of weld strength.

ABSTRACT: The maximum stress on the weld occurs because of differences in expansion between the welded leads and the potting compound. A simple formula is shown for estimating these forces and it is evaluated for some of the more common materials. Acceptability limits can be calculated from weld strength data. If the distribution is assumed to be Gaussian, the probability of failure can be calculated for a given safety margin.

Some of the metal combinations which are weaker in an absolute sense may have lower strains imposed due to relative expansion; they may thus be less likely to fail in this circumstance. Copper-nickel welds as compared to nickel-nickel welds are an example of this phenomenon.

REVIEW: The idea of estimating the destructive forces on the weld is a good one. It is valuable also to point out that the criterion for strength is not absolute but may in some circumstances be related to the stresses imposed. The implication that the formula is exact is unfortunate. There are several statements in the paper which are obviously not intended to mean what is said, e.g.,

1. "The cross-sectional area of the lead ... (is) directly proportional to (its) diameter."

2. This approach is the best method ... because "It is based on a statistical analysis of the problem and no arbitrary assumptions are necessary."

In general, the ideas in the paper are worthwhile and should prove helpful. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1354
Codes 782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effects of a simulated space environment on insulated wire

AUTHOR: H. S. Adams, Materials Technology Department, Hughes Aircraft Company, Aerospace Group, Culver City, California

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 67-73

PURPOSE: To describe an investigation to find the most suitable insulated wire for use in Surveyor spacecraft in a lunar environment.

ABSTRACT: Experiments have been performed to determine the most suitable insulated hookup wire for use in a lunar environment. Extensive tests were made in a simulated lunar environment on the current-carrying capabilities, outgassing characteristics, and flex life of the three insulations: TFE Teflon, Surok, and irradiated polyolefin. Flex tests were made with various stranded conductors of pure copper and Alloy 63 at -315°F.

It was determined that copper and Alloy 63 conductors are suitable for use in space. Increased flex life offered by Alloy 63 permits the use of 24 AWG minimum wire size instead of 22 AWG with a resultant weight saving of about 30%. Alloy 63 has approximately 90% the conductivity of copper.

TFE Teflon is the most desirable of the insulation materials investigated from the standpoint of resistance to the space environment, and Surok is a close second. If weight saving is also considered, Surok offers the best compromise. All three insulations release condensable materials under vacuum at elevated temperatures and it is recommended that insulated wire for spacecraft be pre-treated to remove contaminants; pre-treatment of TFE Teflon and Surok can be accomplished by an exposure of full spools of wire to 10^{-5} torr and 260°F for one week.

The current-carrying capabilities of wire insulated with TFE Teflon appear to be slightly superior to those with Surok insulation.

REVIEW: This paper contains some useful information on the expected behavior of insulated wire in space. The results of the outgassing test of the insulator materials need to be supplemented with mass spectrometer measurements for complete information. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Insulation for military electronic transformers

AUTHOR: J. G. Howe, High-Voltage Specialty Transformer Section, Distribution Transformer Department, General Electric Company, Holyoke, Massachusetts

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 92-98

PURPOSE: To classify the major insulation systems for military electronic transformers with respect to different design conditions, and to describe and clarify several of the insulation systems which are needed to fill the complete range of environmental conditions.

ABSTRACT: The range of conditions to be met by different military transformers is so broad that no one major insulation can satisfy every individual specification. At best, even the optimum insulation for a given application has to be compromised to meet the complete specification involved.

Each suggested insulation choice itself could be the subject of volumes regarding its properties and use. There are many gray areas on the application chart where the optimum selection may be of one or another material. The intent of this paper has not been to describe in detail the exact properties of the fourteen suggested materials nor to make decisive, undisputed choices as to when to use each material. Instead, the objective has been to take a broad look at all the available major insulations, both the standard materials and those which are only recently available and to correlate them with the most important design requirements.

The old standby, transformer oil, is still the best choice for most high voltage applications especially since it can be now used with thermally upgraded paper at higher temperatures. Because of its combination of excellent dielectric and physical properties joined with very low cost, there should be real, positive, justification for the use of some other material in place of transformer oil.

The insulations discussed are: transformer oil, Askarel, air, SF_6, $C\text{-}C_4F_8$, C_3F_8, C_2F_6, gas and evaporative cooling, FC-75 fluoroliquid, FC-43 fluoroliquid, polymethylsiloxane fluid, silphenylene fluid, epoxy encapsulation, silicone elastomer encapsulation. The primary considerations are: ambient temperature, maximum allowable operating temperature, power level, voltage level, and permissible flammability (regardless if tanked or not).

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Twenty-seven pertinent references are cited. (Author in part)

REVIEW: This is a good review paper for designers since it gives a broad picture. As the author infers, it must be supplemented by detailed considerations in each case. Generally, the discussion concerns transformers in the kilovolt and high power range. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1356
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation effects on insulation--state of the art

AUTHOR: V. J. Linnenbom, Head, Radiation Effects Branch, Radiation Division, U. S. Naval Research Laboratory, Washington, D. C. 20390

SOURCE: Insulation, vol. 10, March, 1964, pp. 21-26

PURPOSE: To review some of the recent developments in the radiation effects field, not comprehensively but rather highlighting only certain areas of particular interest to the author.

ABSTRACT: Radiation is only one of several environmental factors which can affect the performance of insulating materials. Because of experimental difficulties, much of the earlier work on radiation effects completely ignored the possible effects of other environmental factors. The present trend in radiation effects studies shows an increased awareness of the necessity of investigating combined environmental effects rather than radiation alone. Examples are cited for the combined effects on insulating properties in a high temperature and radiation environment, in a low temperature and radiation environment, and in a low pressure and radiation environment. The necessity for combined effects studies is demonstrated by the cited results which show that the combined effect of two or more environmental factors may be either greater or less than the sum of the separately-determined effects.

Radiation-induced conductivity changes in insulating materials is an example of a radiation effect which is also sensitive to other environmental factors. Therefore the combined effects will determine the transient behavior in components and circuits operating in environments associated with nuclear reactors and space vehicles. Specifying a circuit performance in these environments is still largely empirical, where the components and completed circuit are tested in a radiation field to determine their ability to operate satisfactorily within the design requirements.

REVIEW: The combined environmental effects are given adequate treatment with respect to the fundamental phenomena; however they receive too little attention in the discussion of the practical aspects of radiation effects on insulating materials. For example, it would be of interest to know more about the state of the art in pre-selecting materials and components for designing circuits which must operate in a combined environment. In reply to this comment, the author, in a private communication, has pointed out that "... for this type of publication one cannot expect a detailed discussion on the more technical aspects of any subject. The presentation must be aimed at salesmen as well as engineers, and consequently is written from an elementary point of view, which would explain why the pre-selection of materials and components for radiation-hardened circuits is not treated in detail." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1357 -1
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aspects affecting the reliability of a carbon composition resistor

AUTHOR: Herbert Y. Tada, Hughes Aircraft Company, Culver City, California

SOURCE: IEEE Transactions on Component Parts, vol. CP-10, pp. 67-79, June, 1963

PURPOSE: To analyze the drift and failure mechanisms in carbon composition ceramic cased resistors.

ABSTRACT: The resistors considered in this paper are made as follows: Two tin-coated copper lead wires are embedded at both ends of an almost cylindrically-symmetric carbon resistance element consisting of carbon granules bonded by an organic resin. The resistance element is molded into a cylindrical layer of silicon oxide impregnated with phenolic plastic, which constitutes the inner case of the resistor. The outer case is a fused ceramic tube containing a high percentage of magnesium and silica, with lesser amounts of aluminum and iron. The inner case is inserted in the ceramic tube and thin nickel sheets are placed over the ends, which are hermetically sealed with silver solder.

The carbon granules are not uniformly distributed, there are cracks and voids in the resin mixture, and the leads are not well bonded. All these effects cause non-uniform heating and current noise. The seals are not always hermetic and the influx of moisture and other gases is deleterious. The behavior of the part is thoroughly discussed and reasons for the drift and catastrophic failures are given in terms of the constructional defects. These resistors have the following obvious limitations:

1. Since the aging processes are accelerated under a pulse environment, the device, whenever possible, should not be used in pulse circuits or should be heavily derated for such circuits.

2. Ambient temperature, or variations of ambient temperature, should be moderate. This restriction is obvious from the aging mechanism.

3. Since the noise level is inherently high and is aggravated by the poor lead contacts, the device is not suitable, generally for low-level-signal circuits.

4. As the power rating increases, the rate of aging also increases. Thus for long part life, the power level should be held below the nominal maximum value as much as possible.

5. Mechanical stresses such as vibration or shock should be avoided since the generally poor lead-wire connections will lead to excess noise generation and instability of the resistance. Improvements in the manufacturing (and screening) processes could materially improve the resistors.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This is a comprehensive qualitative (no numbers are given) description of carbon composition (ceramic encased) resistors. The manufacturer(s) are not identified. By contrast with the discussion of catastrophic failures it is worth noting that a prominent manufacturer of hot molded resistors advertises "At least ten billion field-proven resistors--with not one catastrophic failure--conclusively attest to their reliability."

The article should prove valuable to those interested in the physics of failure of these resistors. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1358
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life improvement of electron tubes

AUTHOR: Keith R. Barker, Western Electric Company, Allentown, Pennsylvania

SOURCE: The Western Electric Engineer, vol. 7, October, 1963, pp. 25-30

PURPOSE: To show some of the improvements made in tube life.

ABSTRACT: The cost of maintaining telephone equipments requires a tremendous expenditure every year both in terms of labor and replacement tubes and also in terms of lost service. Thus, it is apparent that any improvement in the operating life of tubes represents an appreciable savings. This article discusses the major causes for tube failure and traces developments in life improvement over the past several years. Included are discussions of special cathode blank cleaning procedures, double and triple carbonate cathode coatings, high purity nickel alloys, tungsten-rhenium alloys for heaters, and outgassing of anodes. Each of these phases is discussed in some detail and there is a short section giving background on tube failure mechanisms. Changing to the double carbonate coating, controlled high-purity nickel and special cleaning procedures have produced tubes whose transconductance and cathode activity remain reasonably constant for at least 30,000 hours.

Work is being done to further improve the life. (Author in part)

REVIEW: While this article is reasonably detailed and quite interesting, it is for general information and not for reference. A reviewer would find it difficult to do anything but praise this sort of work being done by the Western Electric Company in view of their success in this area. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1359
Code 770

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Memos on reliability and quality assurance: Testing

AUTHOR: Chester Gadzinski, Staff Columnist

SOURCE: Electronic Production, vol. 3, November-December, 1963, pp. 22-23

PURPOSE: To review the kinds of testing done by engineers.

ABSTRACT: Testing consumes a large part of any development program. It is important in production. One may categorize tests as engineering evaluation, qualification, reliability, classification, process control, and product acceptance. The paper gives a summary of each.

REVIEW: This is a very general paper and could be useful for orienting purposes. It is not a paper that one would need for reference. The categories of tests are arbitrary to a certain extent, as is natural. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1360
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Production aids: Weld failures in 300 s.s. components -- How to avoid them

AUTHOR: G. H. Silver, Staff Columnist

SOURCE: Electronic Production, vol. 3, November-December, 1963, pp. 28-29

PURPOSE: To describe causes of and corrective measures for weld failures in Type 300 stainless steel.

ABSTRACT: Of all the stainless steels in use today those of the austenitic chromium-nickel family are probably the most popular. Most of these alloys require welding, and many times failures occur for which there appears to be no reason. In the past, we have had questions posed relative to these so called "unexplained" failures and we hope that this paper gives an insight into avoiding such failures.

The austenitic chromium-nickel steels make mechanically satisfactory welds; but, under certain conditions, they tend to show what is commonly called weld decay. When they are heated within a temperature range of 800 to 1600F or cooled slowly through the range, the carbon is precipitated from solid solution mainly at the grain boundaries; that is, the carbon intergranularly unites with chromium to form chromium carbide. The commonly held belief is that the adjacent areas, impoverished in chromium, have a much lower resistance to corrosion than the remainder of the metal and when exposed to corrosive conditions--corrode. The severity of corrosion depends on the time and temperature of exposure as well as the composition and prior treatment of the steel.

Several methods can be used to combat intergranular corrosion in a weldment made from an austenitic chromium-nickel steel. One such means of removing susceptibility to intergranular corrosion resulting from welding is by appropriate heat treatment of the welded structure when feasible. Another effective means of preventing intergranular corrosion is by the addition of either titanium or columbium. These elements tend to fix the carbon by forming titanium or columbium carbides, thereby preventing the formation of chromium carbide. Structures of these stabilized types (321 and 347), properly welded give excellent results. (Author in part)

REVIEW: This is a physics-of-failure type article and should be of use to both design and production engineers. It demonstrates the importance of knowing the details of what is going on. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Solid-state ignition

AUTHOR: H. C. Welch, Scintilla Division, The Bendix Corporation

SOURCE: 6 pp., presented at the International Summer Meeting, Montreal, Canada, June 10-14, 1963, Society of Automotive Engineers paper 704A (summarized in SAE Journal, vol. 71, October, 1963, pp. 95-97)

PURPOSE: To point out the performance and reliability improvements which should result from the application of solid-state switching and distribution techniques to spark-ignited internal combustion engines, and to discuss some results of work in this area to date.

ABSTRACT: In the order of their importance, the characteristics of an ignition system which are the most critical are: (1) reliability, (2) spark plug life, (3) firing accuracy, (4) voltage output, and (5) cost. Taking these factors into consideration, it appears that solid-state ignition systems, using transistors, controlled rectifiers, zener diodes, etc. will offer substantial improvements over presently-used mechanical systems.

The breaker in an ignition system is, by far, the part with the highest mortality rate. In present electromechanical systems it suffers not only from mechanical wearing but also from electrical erosion due to the arc which occurs when the contact points are separated. The function of the breaker is readily performed by a silicon controlled rectifier. Such a "breakerless" system, i.e. an ignition system in which a controlled rectifier replaces the conventional electromechanical breaker, has been developed and has been in continuous field operation for over one year without service on small air-conditioning engines. The design which was used gives a consistent firing accuracy to within one degree, and this accuracy is not subject to change with operating hours.

On engines where long shielded leads to the spark plugs are required and spark plug fouling with electrode erosion is of major importance, e.g. aircraft engines, the high-tension distributor is replaced by a low-tension carbon brush distributor and individual transformer coils are mounted on top of the spark plugs. As a result, the secondary capacitance and the high-voltage insulation requirements are reduced to a minimum.

Considerable work also has been done on an ignition system which would use solid-state switching not only for the function of the breaker but also for the function of the distributor. Such a system should be capable of continuous operation for a year or more without service.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

REVIEW: As the author points out, there is considerable opportunity for a significant improvement in the reliability of ignition systems through the use of static switching elements and other solid-state devices to perform the necessary switching and distribution functions. This paper gives an excellent summary of the major factors to be considered in attempting to improve the reliability and the performance of ignition systems, and it is in this discussion of ignition system problems and requirements rather than in the presentation of circuit techniques that the main value of this paper lies. Little discussion is devoted to the economic considerations which are having a major influence on the rate at which the already available solid-state devices and circuit technology are being applied to ignition systems. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1362
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductors in electronic ignition systems

AUTHOR: Howard F. Weber, Motorola Semiconductor Products Division, Motorola, Inc.

SOURCE: 12 pp., presented at the International Summer Meeting, Montreal, Canada, June 10-14, 1963, Society of Automotive Engineers paper 704D (summarized in SAE Journal, vol. 71, October, 1963, pp. 41-45)

PURPOSE: To describe in considerable detail some of the important factors involved in the selection of semiconductor components for ignition systems and in the design of these circuits for reliable operation.

ABSTRACT: Some of the newer semiconductor devices, particularly transistors and gate controlled switches (PNPN devices), can be used to improve significantly the efficiency and reliability of automotive ignition systems. Proper design of such electronic systems, however, requires special attention in the selection of semiconductor characteristics and in certain areas of circuit design.

Because of transient intervals of high dissipation to which a switching transistor in an ignition system is subjected, a thorough examination of the operating load line of the transistor should be made. Safe areas of operation in graph form are provided for many transistors by the manufacturer. Major problems in these solid-state ignition circuits are inductively-caused voltage surges and capacitively-caused current surges. Capacitive shunting of leakage inductance and the use of zener diodes are examples of measures used to avoid possible damaging effects from such transients. Conditions which might possibly give rise to destructive transients must be recognized, thoroughly examined, and adequate protective measures taken. Otherwise the potentially very high reliability of solid-state ignition systems will not be realized in practice. Examples of typical design problems are provided.

The silicon gate controlled switch, a PNPN device, has recently become available and is well suited for solid-state ignition systems. With this device, one of the major design problems is that of providing an adequate turn-off pulse at the proper times. A primary advantage of this device is its high-voltage capability.

REVIEW: This paper reviews in considerable depth some of the circuit design problems involved in the use of semiconductor devices in electronic ignition systems. It makes very clear the fact that, while such solid-state systems potentially offer substantial advantages, the actual degree to which these advantages are realized depends directly on the adequacy of the system design. An excellent perspective is provided by this paper of some of the technical considerations which are required for proper design. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1363 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The unreliability of electronic apparatus and its causes

AUTHOR: H. J. Frundt

SOURCE: N. T. Z., 13 (11), 524-528, 1960, Germany, translated and issued November, 1961 by Technical Information and Library Services, Ministry of Aviation (ASTIA Document No. 271426)

PURPOSE: To discuss the basic principles of the analysis of the unreliability of electronic apparatus and its causes.

ABSTRACT: The continuing progress of modern technology demands greater automation. Satisfactory use of automation demands good reliability and, in general, the reliability of present electronic apparatus is not sufficient.

Electronic apparatus contains two general types of components: (1) components subject to physical wear and therefore having a relatively short life (e.g. valves, motors, mechanical vibrators), and (2) components showing no physical wear (e.g. capacitors, resistors, transformers, etc.) In the case of attended apparatus, type (1) components will be replaced before failure as a part of normal maintenance. Therefore, the principal question in reliability of apparatus concerns components of type (2).

For all types of attended electronic apparatus, a composite statistical average failure rate curve has been determined by long observation. The failure rate in failures per hour plotted against time in hours has the so-called "bathtub" shape with initial (high), normal (low and constant), and final/wearout (high) regions. Equipment should not be delivered for use until the normal operating period is reached and should be replaced at the onset of wearout. The customer is then concerned only with the failure rate during the normal operating region. Since the failure rate is constant during this period, the usual expressions and results for the negative exponential distribution of times to failure will hold. Some formulas for series and parallel configurations are given, assuming that failures occur independently.

In electronic apparatus, any component failure often causes the failure of the whole apparatus. In such cases, the failure rates of the individual components are additive and the more components, the smaller the reliability of the apparatus. This reliability can be improved by using the minimum number of very high quality components, assembled in such a way as to minimize the deleterious effects of thermal stress, vibration, shock, and mechanical stress. Also, if a component fails in an "opening" or "shorting" mode, the technique of redundancy may be used to ob-

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

tain greater reliability. For those elements that fail by opening, a parallel redundancy is used, and for those components that fail by shorting, series redundancy is effective. A third and less useful approach is the technique of over-designing components such that they will be worked far below their rated loads. Examination of available data shows an average failure rate of 10^{-6}/hour for components of type (2). It is also determined that the failure rate for large computers and all types of radio apparatus is an order of magnitude greater than is currently desirable.

REVIEW: This is all material that is available in English without the necessity of translation. It is very elementary and has the usual limitations associated with that approach. Some information is given as to the state of the art at the present time but no really instructive mathematical or theoretical development is offered. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1364 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A study of semiconductor reliability

AUTHOR: B. A. Bowen

SOURCE: 31 pp., Syracuse University Research Institute, College of Engineering, Electrical Engineering Department, Report No. EE751-6106TN2, RADC-TN-61-131, June, 1961, sponsored by Rome Air Development Center, Contract No. AF30(602)-2177 (ASTIA Document No. 263625)

PURPOSE: To report on the first phase of a study of the mechanics of failure of semiconductor devices.

ABSTRACT: The obtaining of transistor reliability data is affected by two important considerations. Time and money must be expended and both are necessary. Because of the large cost in time and money, it is not feasible to subject a unit to tests until it has become a standard production item, relatively free of abrupt changes in its manufacturing process. This delay in obtaining reliability data may be as long as two years or more and the data may not be of interest when available.

An adequate program for testing reliability of a unit should include the following: (a) test for the mechanical soundness of the wafer mounting, the lead attachments, and housing seals, (b) test for initial atmospheric conditions and leaks during the sealing of the housing, and (c) test of the ability to withstand thermal cycling. Three main criteria for long life are: (1) a clean surface, (2) an evacuated housing, and (3) a leakproof seal. Useful reliability data demand that the test sample of a unit be truly representative of the production models and that the concept of failure to be used be completely defined. At present, a complete knowledge of transistor manufacturing techniques is essential for design considerations.

There are two main causes of failure in the junction transistor. The most important effect is parameter deterioration induced by surface contamination. It is known that the chief contaminants are water vapor and oxygen. These two agents may act alone or in combination. The second major cause of failure is change in the bulk properties of the material due primarily to impurity diffusion through the junction. This effect is most noticeable in very thin layers or in devices possessing very steep concentration gradients. Device reliability can be predicted most accurately by studying basic failure mechanisms and understanding inherent weaknesses. Ultimately a knowledge of the surface condition at a given time, of the surrounding atmosphere, and of any possibility of leaks in the housing should be enough to yield a predicted life expectancy.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

A bibliography of 24 items is given. Pertinent mathematics on diffusion calculation, analysis of the diffusion model, and analysis of the approximate error function model are presented in three appendices. A proposal for extension of the work is reproduced in a fourth appendix.

REVIEW: The author has made a very thorough search of the literature and has reached some interesting conclusions. The concept of predicting reliability by obtaining a more basic understanding of the physical nature of the device should be fully developed. This report should be of considerable value to others working in this area. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Second breakdown; effects of base drive and structural defects

AUTHORS: H. A. Schafft and J. C. French, Electron Devices Section, Instrumentation Division, National Bureau of Standards, Washington, D. C.

SOURCE: A talk presented at the Professional Technical Group on Electron Devices Meeting, Washington, D. C., October 31, 1963, National Bureau of Standards Report 8122

PURPOSE: To describe the effects of base drive and structural defects on the operation of a transistor both before and after the initiation of second breakdown, and to point out the usefulness of temperature-sensitive phosphors and base current modulated tetrodes as tools for studying internal current distributions.

ABSTRACT: Second breakdown in transistors, commonly recognized by an abrupt reduction in V_{CE}, has associated with it a marked constriction in the current distribution. This constriction has been observed, by monitoring the current modulated base resistance in tetrode transistors and by observations of the current distribution (through the associated temperature distribution) with the aid of temperature sensitive phosphors. The results of using such phosphors in studying the behavior of current distributions in alloyed germanium transistors and diodes in conjunction with various electrical measurements are reported.

Under both the normal and second breakdown operating conditions that were examined, it appears that the application of a forward base drive has the effect of diminishing any current concentration that is present while the application of a reverse base drive has the opposite effect. There is a minimum current through the current constriction below which second breakdown is not stable. Because the base drive can modify the current through this constriction, it is possible to bring a transistor out of the second breakdown condition with the application of a sufficiently large forward base current. Second breakdown can occur at any of a number of susceptible locations in the transistor. Base current will modify the current distribution so that second breakdown will occur at a susceptible site which exists in the region where the base drive has produced the highest current density. (Authors)

REVIEW: The major contribution of this paper is added clarification of the role of base drive upon the characteristics of second breakdown (SB). The influence of base drive is so pronounced that transistor operation in an SB mode is easy to visualize. This new information, added to the authors' previous work (see Abstract and Review Serial Number 1347), forms as complete and unified a

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

description of the behavior pattern of SB as is presently available. No further explanations of the cause of SB are offered, although the relationship between hot spots (presumably developing around structural defects) and the occurrence of SB is confirmed.

While the effectiveness of the temperature-sensitive phosphors for this application is undeniably demonstrated, their advantages over temperature-sensitive paints such as used by Scarlett and Shockley (see Abstract and Review Serial Number 1378) are not explicitly stated. In a private communication the first author has supplied the following discussion of this point. The paints indicate the extent of only one isotherm whereas the phosphor is able to display a two-dimensional temperature profile over a considerable range of temperature for a given intensity of excitation. The range of temperature over which a temperature profile is observable can also be shifted merely by changing the intensity of the exciting radiation. The phosphor is illuminated with near ultra-violet radiation throughout the experiment and excitation is not really an extra step of preparation. The extra "labor" of this step is quite negligible because the ultra-violet light replaces the incandescent light otherwise needed to view the paint. The paints either melt or evaporate upon reaching or passing through the rated temperature. In the latter case the evaporated paint must be replaced after each application of power. In the former case the change in texture of the paint after drying is often such as to make difficult observations of more than one operating condition. In addition the time needed for the paint to dry is often inconveniently long. Thus, for example, when one attempts to view the second breakdown current constriction a large area of the paint will often have already melted because of the dissipation that occurred during the delay time. Excessively long operation in the second breakdown mode would then be needed to allow enough paint to dry to define the site of the current constriction. The phosphors suffer from none of these disadvantages in that the response to changes in temperature is rapid and reproducible.

The second technique recommended by the authors is the observation of the current-modulated transverse base resistance of a tetrode transistor. Only three sentences in the text are devoted to this technique and no data are cited to develop the conclusions in the paper, leaving the impression that the authors consider this technique to be subordinate to that employing phosphors. The first author, in a private communication mentioned above, has stated that the authors regard this method as a way that might be useful in measuring and studying the more rapid and subtle changes in the current distribution both before and after the occurrence of second breakdown. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fallacies in failure concepts and application of modern reliability theory

AUTHOR: Robert A. Kirkman, Space Technology Laboratories

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 123-145

PURPOSE: To point out what is wrong with modern reliability practice and to suggest improvements.

ABSTRACT: The reduction and control of failures in electronics systems is essential due to (1) the need for maximum safety of personnel on exotic missions; (2) the long unattended life required of space systems; (3) the high dollar costs to buy additional systems and support additional maintenance personnel required to compensate for the unreliability and system down-time.

As practiced by advanced organizations, efforts to reduce parts failures by design controls and conventional statistical reliability methods are a necessary condition of reliability, but not a sufficient one.

For clarity and background, present reliability and failure rate theory and practices are reviewed briefly and some limitations are pointed out. The physics and the mechanisms of actual failures are discussed and it is pointed out that failures follow the laws of cause and effect; that they are therefore intrinsically predictable. The concept of random failures is valid in a statistical sense but it should not discourage efforts to predict and prevent individual failure by all means open to us. A powerful method of failure prevention is a thorough system test prior to use when the test is geared to look for failures where they can be detected.

Lack of precision in terminology is part of the problem of failure control; we commonly intermingle references to failures by source, by cause, by end-effect, and by symptom. An improved organization and definition of failures is developed through which the methods, means, and limitations of failure detection, prediction, and prevention can be established.

Using the background developed, a flexible but quantitative definition of failures in a mature system, useful in their prevention, detection, and in defeating their consequences, is formulated.

Specific methods of predicting failures are identified and it is

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

pointed out that a mixed strategy is essential to reliability. The most important and novel of failure prediction methods is comprehensive testing for the presence of failure symptoms and causes at times, and under conditions, where a future break-down can be predicted. The approach, which can be thought of as a sophisticated kind of preventive maintenance, is capable of reducing failure rates to values below those currently published, thus improving reliability. This is made possible by playing a different and more advantageous game than that under which the published failure rate data were generated.

REVIEW: If this paper is read as a general essay on "what is wrong with reliability?" it has much merit. Many of the suggestions for improvement are worth reading and thinking about. However, so many statements are so inexact and/or not clear that to study the paper as a scientific treatise is not worthwhile.

Two of the good points in the paper are the following.

1. Emphasis on the distinction between the reliability which is calculated on the basis of an extremely simple-minded concept of the system and the actual use reliability of the system.

2. Emphasis on the fact that "random failures" have physical causes which are in principle determinable, and the fact that often serious confusion and misconceptions exist between statistical concepts and cause-and-effect or deterministic approaches.

Even though the second point is made, the following additional discussion on it is appropriate: The occasions for the use of statistics of random variables to describe events can be put roughly into three classes as follows: (1) situations in which we cannot know anything more detailed about the process than the statistical description, e.g., quantum mechanics; (2) situations in which it is hopelessly involved to evaluate individual behaviors and effects, e.g., statistical thermodynamics; and (3) situations in which we do not want to be bothered with details and are willing to lump things together into a few numbers, e.g., a census. The use of statistics for failures falls somewhere in classes (2) and (3), depending on the application. Thus the use of the term "chance" failure describes our attitude rather than the ways of nature.

In a private communication the author has commented as follows: "The subject paper was not prepared for publication in a bound book and has not been edited for that purpose. On the one hand, it is wordy in an attempt to clarify in an ill-charted and often misunderstood area. On the other, in some cases where I decided to save words, probably more clarification or qualification is needed." He has further contributed the essentials of the above ABSTRACT. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1367
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dislocations and semiconductor device failure

AUTHOR: H. J. Queisser, Shockley Transistor, Unit of Clevite Transistor, Palo Alto, California

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 146-155

PURPOSE: To discuss the harmful effects of dislocations upon the performance of silicon devices, and methods of reducing or avoiding these effects.

ABSTRACT: Even though dislocation-free silicon can now be grown, devices cannot be made free of dislocations because the manufacturing processes introduce large numbers of dislocations over and above any that may be present initially. Consequently dislocation-free silicon cannot be expected to yield devices superior to those of non-dislocation-free silicon. The absence of a proven direct effect of dislocations upon device performance suggests the inadequacy of the dangling bond description of a dislocation. An alternative description is to picture a dislocation as an atomic arrangement involving no broken or unsaturated bonds.

Indirect effects of dislocations manifest themselves as irregularities in diffused junction depths and impurity profiles and as nucleation centers for the precipitation of metals and oxygen. Both of these manifestations are shown to adversely affect device performance. It is also possible that oxygen impurities saturate the "dangling" bonds surrounding a dislocation, and thereby mask the expected influence of such "dangling" bonds upon electrical performance.

REVIEW: This paper reports on what appears to be a systematic investigation of the role of dislocations in silicon device performance -- something which is lacking in the literature. The subject is fundamental and of great interest not only to the physics of failure but to solid state physics in general.

The discussion in this paper is totally qualitative but the picture that emerges is both clear and reasonable. It is an excellent survey paper for readers not actively working with dislocation effects. Those who are will find original ideas in considering impurities and dislocations as interacting defects.

The author does not give any practical methods for reducing or eliminating the harmful effects of dislocations, as he indicated he might. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1368
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effect of gas ambient on the failure of traveling-wave tubes

AUTHOR: R. A. Hein

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 156-166

PURPOSE: To describe tests made on the gas content of traveling-wave tubes (TWTs) and its relationship to tube behavior.

ABSTRACT: Previous work has been done on the subject of detrimental effects of gas in tubes. The present tests used an omegatron as a gas analyzer; it was applied to high and medium power TWTs. The high power tubes contained N_2, H_2, and He (abnormal ones also contained argon). The medium power tubes contained N_2, H_2, CO, CH_4, and argon.

The quantitative relationship between total gas pressure and perveance has not yet been determined. Qualitatively, we can say that there does appear to be a correlation between total (or partial) pressure of a gas and the measured cathode current of an oxide coated cathode. This deterioration of cathode current can then be related to tube failure in terms of reduced power output.

In addition we have found evidence of a period of aging of a medium and high power TWT during which time the partial pressures of the gases in a TWT increase to a maximum and following the maximum, decrease to an equilibrium point. (Author in part)

REVIEW: So far, these results appear to be only preliminary--no definite evidence of "causes and effects" vital to tube behavior has yet been found. This type of study is important and hopefully will lead to the desired information--which may then have wide application. (See also the paper covered by Abstract and Review Serial Number 1369.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1369
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Omegatron investigation of gases evolved from components of TWT's under operating conditions

AUTHOR: M. Friedman Axler, General Telephone & Electronics Laboratories, Inc., Bayside 60, New York

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 167-178

PURPOSE: To describe experiments for determining the kind of outgassing from travelling-wave tube (TWT) heaters.

ABSTRACT: It is recognized that the test conditions of the travelling wave tube heaters are not identical to those in the operating tube. Some differences between the operating travelling wave tube and the experimental procedures described in this paper, are, for example, that the heater coil in an operating travelling wave tube is at a higher temperature than in a test bulb due to lower radiation losses. This feature would, however, tend to compound the effects found so far in this investigation. Additional differences are the interaction of the gases evolved from the hot heater coil and other gases on surfaces in the travelling wave tube, and the effect of these phenomena on subsequent heater cycling.

Despite these differences, the conclusion can be drawn that the coated heater coil is a source of gas in a travelling wave tube, the chief gas being N_2.

The data in the paper present a significant fact: whereas in these experiments in which a coated heater is studied as a separate unit, it is found that one coil pumps a gas and the other does not, the experiments that have been performed on the travelling wave tube do not exhibit the first phenomenon. This would indicate that there are additional adsorption and desorption processes occurring in the more complex structures of the electron tube. After the investigations of other tube components with the omegatron are completed, experiments will be performed on sub-assemblies of the travelling wave tubes in order to determine more specifically the nature of the problem. (Author in part)

REVIEW: This is a companion paper to the one covered by Abstract and Review Serial Number 1368. The review of that paper applies also to this one. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1370 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thermal instabilities and hot spots in junction transistors

AUTHORS: R. M. Scarlett, W. Shockley, and R. H. Haitz, Shockley Transistor, Unit of Clevite Transistor, Palo Alto, California

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 194-203

PURPOSE: To show how thermal instability arises in uniform transistor structures and to relate such instability to the "second breakdown" phenomenon.

ABSTRACT: A lateral thermal instability has been observed on a number of different power transistors. At a certain critical internal temperature rise, current density and temperature tend to build up in one small region of the device, resulting in a hot spot. The temperature at the hot spot may be very much higher than that expected on the basis of uniform current distribution over the entire device area, producing localized alloying or diffusion resulting in early failure of the device. It is believed that the "secondary breakdown" observed on most transistors results from the development of a hot spot.

A two-dimensional analysis shows that thermal instability should be present even in ideal device structures. However, various defects such as thin spots in the base layer or imperfect alloying to the heat sink will act to initiate the instability at a lower level than in the ideal case. Experiments indicate that both the theoretically predicted thermal behavior and the influence of defects can be observed.

Hot spots have been investigated in some detail on a particular development silicon power transistor by means of temperature sensitive paint, and by potential probing of the aluminum emitter contact to determine the current distribution. Diameters of the order of 100μ and temperatures of over 300°C are observed in agreement with estimates made from a simple model. (Authors)

REVIEW: The experiments reported here complement the work of Schafft and French (see Abstract and Review Serial Number 1347) in that they elaborate upon a thermal mechanism such as proposed by those authors as a likely mechanism for the "second breakdown" phenomenon. A theoretical model is described, which predicts unstable operation when the temperature rise caused by an increased current flow is itself sufficient to cause a further increase in current equal to or greater than the original current increment. The paper also presents experimental measurements made on power transistors that substantiate the proposed model quantitatively.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

The descriptions of the experiments are not easy to follow, so that some uncertainty may remain in the reader's mind as to what has occurred or why. For example, in the explanation of the experiment on thermal resistance, the following ambiguous sentence appears: "Because a smaller junction voltage is required to sustain a given current at higher temperature, the thermal time constant of the device under observation is of the order of 10 ms." In subsequent publication of this material (see Abstract and Review Serial Number 1378) this section has been improved by rewording.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Current noise measurement as a failure analysis tool for film resistors

AUTHOR: J. G. Curtis, Corning Electronic Components, Corning Glass Works

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 204-213

PURPOSE: To isolate the causes of noise variability in tin-oxide resistors and to correlate this variability with other performance factors.

ABSTRACT: Noise in resistors is of two types: thermal noise ("Johnson noise") and current noise (excess noise). This paper discusses the latter, which occurs only when a current is passed through the resistor. Because of its inverse dependence on frequency it is sometimes called 1/f noise. In addition it is generally directly proportional to the current flow and inversely proportional to the number of discrete conducting particles active in the resistor. Current noise is measured as μv of noise per volt of applied dc and is usually written as a noise index (db) given by

$$20 \log [\text{noise voltage } (\mu v)/\text{applied voltage } (v)].$$

Of the various tin-oxide resistors whose noise index was checked, a small percentage exhibited abnormally high values which could be traced to mechanical defects such as scratches, pinholes, cracks, or chips in the tin-oxide film or to high resistance contacts. A comparison of the noise index with the resistor temperature coefficient and the percent resistance change during a standard 1000-hour cycled full load life test revealed that a discrete noise level existed which could have been used to remove all drift and temperature coefficient "mavericks" (along with a number of good resistors). The conclusion is that the noise index may be a valuable additional parameter for predicting resistor performance.

REVIEW: The relationship between high noise levels and defects is established in this paper both directly (by visual observation) and by inference (from life tests). It is reasonable to expect that the defects which cause noise can also lead to premature resistor failure, and the author has presented evidence to confirm such an expectation. His caution that the work is preliminary should not lessen its impact or its potential. Quite conceivably the noise index is a more sensitive measure of resistor quality than presently-available and the supposedly "good" units that are culled by the noise index criteria may prove less durable under more severe tests. The author does not comment directly on this possibility but unquestionably is thinking along such

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

lines.

The paper is clear and convincing, although the data presentation (Figures 10-12) is not immediately self-evident. Two tests were actually employed to locate mavericks -- a temperature coefficient test and a full load life test. The results of both tests are shown in each figure with the rejects of the temperature coefficient test being indicated by a special symbol and that of the life test by the scale of the abscissa.

This is the more complete paper referred to in Review Serial Number 263. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1372
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some physical mechanisms contributing to tunnel diode failure

AUTHOR: R. P. Nanavati, Syracuse University

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 214-222

PURPOSE: To describe a study of failure mechanisms in tunnel diodes.

ABSTRACT: The deterioration rate of gallium arsenide tunnel diodes is high when the diodes are statically biased in the forward direction well past the valley, is much less with reverse bias, and has not been observed in unbiased diodes. The deterioration is accompanied by a decrease in junction capacitance and is faster for a higher doping impurity density. These observations are explained by a field-enhanced movement of the host atoms. These atoms, activated by momentum transfer from conduction electrons, move in an electrical field and change the properties of the diodes. Two specific effects of this redistribution are a broadening of the junction transition region and the introduction of defect energy levels in the band gap. This hypothesis is confirmed by the rapid increase of deterioration with temperature, a lower deterioration rate with ac current, a persistence of the deterioration after the bias is removed, and other evidence. It predicts that the deterioration rate is proportional to the band gap for compound semiconductors, to the diffusion constant of the host atoms, and to the doping density. Elemental semiconductors in which the available ion density, the impurity, is low will exhibit a much lower deterioration rate.

REVIEW: The model which is hypothesized here depends on the transfer of sufficient energy from electrons to move atoms from their normal positions in the crystal. While the experimental evidence which supports it is convincing, additional data is desirable before it can be seriously considered. The existence of field-aided diffusion for the host atom in compound semiconductor devices and for substitutional impurity atoms in elemental semiconductor devices would be an extremely important failure mechanism extending beyond just tunnel diodes. If such processes do occur at normal operating temperatures and with normal electric fields in semiconductor devices, it is important to fully characterize them. This could be a fundamental limitation on the applicability of compound semiconductors, particularly for high temperature operation, as well as an important process in elemental semiconductors in particular circumstances, i.e., large electrical fields and large impurity gradients. The large energies required for the initiation of such diffusion, however, makes it unlikely that this hypothesis will hold up as new evidence is obtained. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1373
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some aspects of dielectric degradation in perovskites

AUTHORS: Robert Gerson and Don Berlincourt, Electronic Research Division, Clevite Corporation

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 223-230

PURPOSE: To describe some preliminary experiments on ferroelectric materials for use as capacitor dielectrics.

ABSTRACT: Materials with high dielectric constant (high K) appear to have low dielectric strength. There is some reason to expect a positive correlation of the two due to a common cause. The effort in this program so far has been to prepare and make initial tests on suitable ceramic dielectrics. With perovskite materials (ABO_3) the A position may be filled by a positive ion of large ionic radius, the B position by a positive ion whose radius is 30 to 40% smaller. Pb^{2+}, Ba^{2+}, and Sr^{2+} are A-position elements; Ti^{4+} and Zr^{4+} are B-position elements used in this work. The lead ion provides high polarizability, hence leads in general to stronger ferroelectric interaction than Sr^{2+} or Ba^{2+}. The higher volatility of lead at the firing temperature provides a closer approach to chemical equilibrium. Nb^{5+} and Sc^{3+}, which from size considerations fit into the B-position, have been used to modify the basic materials. Nb^{5+} acts as an electron donor, Sc^{3+} as an acceptor. If the unmodified ceramic is p-type, as is usually the case, the donor tends to raise the volume resistivity by a compensation process. Similar considerations hold for n-type base ceramic doped with an acceptor. The addition of Nb^{5+} or Sc^{3+} profoundly affects the dielectric properties of the base materials as well, as has been noted for off-valency additions to piezoelectric lead titanate zirconate ceramics. Some of the preliminary results are presented in the form of curves of K and resistivity vs. temperature and composition and in scatter diagrams of dielectric strength vs. resistivity and K. (Authors in part)

REVIEW: Hopefully these studies will achieve their aim of finding out more about the nature of ferroelectric dielectrics. In addition to the engineering (direct application) value, there could well be important contributions to the basic knowledge of the behavior of materials. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1374 -1
Codes 711;775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electrical detection of surface effects in transistors

AUTHOR: W. Howard Card, Syracuse University

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 231-245

PURPOSE: To describe four nondestructive electrical measurements which provide information about the surface properties of a transistor.

ABSTRACT: Four experiments are reported. The first is the measurement of the open-circuit voltage on the emitter of a transistor when the collector is reverse biased. The value of this floating potential can be calculated from p-n junction theory; large deviations from the calculated value indicate surface effects. Germanium alloy junction transistors exhibited the calculated values and behavior reasonably well; grown junction and surface barrier germanium transistors yielded scattered results, possibly due to surface leakage between the emitter and base regions. Silicon grown-junction transistors also appeared to have low impedance surface paths (low when compared with the reverse resistance of the emitter-base junction).

The second experiment measures the drift of the reverse current of a p-n junction as a function of time. This drift is thought to be indicative of a surface reaction. An activation energy of 1.26 electron volts was calculated using data from a germanium grown junction transistor. This value agrees with the observation that one volt or so of bias is required before the original reverse current level is not recovered when the voltage is removed.

In the third experiment the effect of an electric field normal to the transistor surface is measured and interpreted. The field is created by applying a voltage to the transistor can so that the technique is applicable only to those devices that have isolated cans. From measurements of collector current and h_{FE} as a function of can voltage (from + 1000 volts to - 1000 volts) the following conclusions were reached: (1) If the can voltage affects only collector-to-emitter conductance, then there is a channel across the base, and (2) If the can voltage affects only the emitter junction or collector junction behavior, then there are local channels in the regions of the boundaries.

The fourth experiment describes measurements of noise arising from non-stationary random processes, presumably associated with the surface. Variable unanticipated results were obtained, including a switching behavior. While the data do not establish

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

any definite relationships, such noise measurements are worthwhile in the general investigation of surface instability.

REVIEW: A major advantage of the experimental work described in this paper is that all the measurements can be made on packaged units, eliminating the damage and unknowns introduced into a failure analysis by removing a protective can. The data are simple, easily-made measurements which require no extraordinary tooling or equipments and yield unambiguous points. However, the interpretation of the results seems incomplete at present.

The floating potential measurements made on certain transistors were described as unsatisfactory due to the assumed presence of low surface-resistance paths between the emitter and base. Since the technique is such that the floating potential is in the same direction as a reverse bias on the emitter-base junction, a useful piece of information would be the reverse resistance of this junction at the value of the measured floating potential. This constitutes a measure of the resistance of the leakage paths. In the same experiment the first of two reasons given for an emitter-to-collector channel not being present on a p-n-p alloy-junction device is that it is "a p-n-p rather than an n-p-n device," implying presumably that emitter-to-collector channels do not occur across n-type base regions. This conclusion is not obvious in view of the many reports of p-type channels on n-type substrates. (See, for example, [1] or [2].)

The technique chosen for the field-effect measurements suggests that the fast states are measured and not the slow states, instead of the reverse as implied by the author. Additional information such as the display of breakdown characteristics would be helpful in interpreting Figure 7. The effect of an external field upon the surface recombination velocity is difficult to predict without knowledge of the zero-field surface potential, and the dismissal of modulated surface recombination as an explanation of Figure 7 seems too facile. The conclusions of this experiment, as quoted in the abstract, are difficult to understand. Probably they state that the behavior shown in Figure 8 is characteristic of channels linking the emitter to collector; the characteristics shown in Figure 9 represent channels across either the emitter-base or base-collector junctions but not extending across both.

REFERENCES: [1] H. Statz et. al, "Measurements of inversion layers on silicon and germanium and their interpretation" p. 139, Semiconductor Surface Physics, edited by R. H. Kingston, Univ. Of Pennsylvania Press, Philadelphia, Pa. (1957)

[2] T. M. Buck and F. S. McKim, J. Electrochemical Soc., vol. 105, p. 709 (1958) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1375
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Microwave losses, dielectric properties and elastic constants of $SrTiO_3$

AUTHORS: Georg Rupprecht, Tyco Laboratories, Inc., Waltham, Massachusetts and R. O. Bell, Raytheon Research Laboratory, Waltham, Massachusetts

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 246-255

PURPOSE: To describe experiments which relate the dielectric and elastic properties of some titanates.

ABSTRACT: The ferroelectric properties which are peculiar to the perovskite structure arise from a temperature-dependent vibrational mode. On this basis the general behavior of microwave losses can be understood. For microwave frequencies (when much below the resonance frequency) the loss tangent and damping factors are expected to be smooth functions of temperature. The deviation of loss tangent below the 110°K transition temperature is thus a surprise.

The detection of a phase transition from a cubic to a tetragonal lattice together with the fact that the real part of the dielectric constant is essentially unaffected by the phase transition suggests that, in this slightly distorted tetragonal lattice, the damping factor is increased.

From the data collected, an interesting conclusion can be drawn. Since the characteristic parameters of ferroelectricity, the Curie constant, C, and the Curie temperature, T_c, are strongly dependent upon the mass of the cations in the investigated series of perovskite structures, one can obtain a mode assignment which characterizes the soft mode as the vibration of the cation against the TiO_3 octahedron. (Authors in part)

REVIEW: The connection of this paper with failure is the possibility that the unexpected variations in dielectric losses may be related to a failure mechanism. As such it is worthwhile research, but rather specialized for the ordinary design engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Diagnostic techniques in semiconductor device stress response analysis

AUTHOR: Conrad H. Zierdt, Jr., General Electric Company, Semiconductor Products Department, Syracuse, New York

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 91-97

This paper is essentially the same as the one covered by Abstract and Review Serial Number 961.

TITLE: Reliability physics (the physics of failure)

AUTHORS: Donald R. Earles and Mary F. Eddins, Avco Research and Advanced Development Division, Wilmington, Massachusetts

SOURCE: Physics of Failure in Electronics, edited by M. F. Goldberg and Joseph Vaccaro, 1963, Spartan Books, Inc., Baltimore, Maryland; Cleaver-Hume Press, London, pp. 179-193

The text of this paper is essentially the same as that of the paper covered by Abstract and Review Serial Number 976.

TITLE: Failure analysis: key to better reliability

AUTHOR: (Editorial Matter)

SOURCE: Electronics, vol. 35, October 12, 1962, pp. 28-29

This is a condensation of some of the papers presented at the Symposium on the Physics of Failure in Electronics, September 26-27, 1962 sponsored by Rome Air Development Center and Armour Research Foundation of Illinois Institute of Technology, Technology Center, Chicago, Illinois. The separate papers presented at this symposium have been covered by Abstracts and Reviews Serial Numbers 1338 through 1348 and 1366 through 1375. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1377
Codes 711;712;773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Vacuum fatigue tester

AUTHOR: B. Steverding, Physical Sciences Laboratory, Army Missile Command, Redstone Arsenal, Alabama

SOURCE: The Review of Scientific Instruments, vol. 35, pp. 565-568, May, 1964

PURPOSE: To describe a simple fatigue tester with the specimen in a vacuum or other atmosphere.

ABSTRACT: The tester described in this paper is a conventional one (constant stress amplitude) for bending (non-rotating) and push-pull type fatigue, but is modified for vacuum studies by adding a bellows around the sample. The bellows is coaxial with the sample and enables the sample and solid support to be in the vacuum or other atmosphere. The construction is reasonably simple and without electronic control apparatus; the bellows does not seem to fatigue during the tests. Curves are shown for vacuum as compared to air for silver, 1020 steel, 7075(T6) aluminum. The performance in vacuum is generally better than that in air.

REVIEW: With the increasing importance of outer space environments, a simple fatigue tester such as this can help provide the designer with information that he needs. Generally the designer himself need not perform these tests, but he should be aware of the need for them. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1378
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Secondary breakdown and hot spots in power transistors

AUTHORS: R. M. Scarlett and W. Shockley, Shockley Laboratory, Clevite Transistor Division, Clevite Corporation, Palo Alto, California

SOURCE: 1963 IEEE International Convention Record, Part 3, New York, New York, pp. 3-13, March, 1963

PURPOSE: To further develop the thermal instability model for second breakdown in power transistors.

ABSTRACT: A model is presented for the mechanism of secondary breakdown. According to this model, secondary breakdown is initiated by a lateral thermal instability in which current and temperature build up in one region of the device to produce a hot spot. Observed temperatures of such hot spots have been over 350°C, which appears to be sufficient for thermally generated current to cause a localized thermal runaway. In such a condition, a given fractional increase in power and hence in temperature rise produces a larger fractional increase of current. The voltage must thus decrease, leading to the observed apparent negative resistance region. Experimental observations of unstable current build-up and hot spot development are reported. (Authors)

REVIEW: This paper extends the ideas previously published by the authors (see Abstract and Review Serial Number 1370). A stability index is defined and measured for a particular power transistor. The "current-hogging" phenomenon of two transistors connected in parallel is also analyzed in terms of the stability index.

Several sections of the text and some of the illustrations in this paper are identical to those in the previous paper. The conclusions of the two papers are also identical. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1379
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The EIA-Military established reliability program

AUTHORS: Leon Podolsky, Sprague Electric Company, North Adams, Massachusetts and J. Howard Schumacher, EIA Engineering Department, New York, New York

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 114-119

This paper is on the same topic as the one covered by Abstract and Review Serial Number 1209. It constitutes, in effect, an updating of the material as of May 1, 1963. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The use of component distribution data in a probabilistic model of circuit performance analysis; an application of the Monte Carlo technique

AUTHOR: H. Ginsberg, Philco Corporation, Western Development Laboratories, Palo Alto, California

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 120-126

PURPOSE: To show the usefulness of component distributions in circuit performance analysis.

ABSTRACT: The worst-case design/analysis suffers from the fact that it gives little information on the ordinary performance of the circuit. If a performance model of the circuit is known, and if the distributions of values of the components are known, the probability curve for circuit performance can be calculated. This is done most easily by a Monte Carlo technique which picks component values at random from the distributions and then solves for the performance using those values. If two parameters of a component are highly correlated, they are not picked at random with respect to each other. Once the performance probability distribution is known, the fraction of good and bad circuits can be found. This analysis can also be used to find the effects on performance of time, "stress," critical components, etc.

REVIEW: The use of component distributions will come to be a vital part of reliability analysis and this paper does a good job in calling attention to it. While the paper does not treat the subject of getting the performance model in the first place, it is worthy of note that the process can be difficult, time consuming and expensive.

The author indicated that further statistical research is necessary. This shows up in his treatment of correlation between several parameters--only the values 0 and 1 are considered. Obviously the correlation may have a value anywhere between these extremes. There will also be important correlations between the component distributions at various "stress" levels and at different times. The treatment of an extremely small fraction of catastrophic failures as well as that of calculating the cumulative density function curve needs more work; the presentation in the paper is rather general.

All in all, the paper fills a need in bringing this important subject to the attention of component and design engineers. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1381
Codes 837;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis and presentation of part degradation data

AUTHORS: B. Tiger and J. F. Wilkes, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 127-132

PURPOSE: To show how parts degradation data can be analyzed.

ABSTRACT: If a good circuit performance analysis is to be made, it is necessary to know how the part parameters change with time and "stress." This paper analyzes the results of a series of tests on resistors. Equations are empirically developed for the means and standard deviations of the distributions as functions of temperature (ambient), power dissipation, and time. A least squares method was used for the estimation of the empirical parameters in the equations. The results are presented. The distributions have not yet been analyzed for the correlations that exist.

REVIEW: The analysis of the distributions of parts' parameters is very important. This paper presents one line of attack. At this time it is not possible to evaluate this approach with respect to others, such as the Monte Carlo method. It is important to pursue the method described here and the authors have done well. They rightly mention the need for analysis of correlations. Work is also necessary in evaluating the uncertainties in the empirical coefficients, and in finding a physical basis for the form of the equations. The uncertainties are especially important in view of the extrapolations that are desired. Comparisons of estimated and measured values for the mean and standard deviation are given, but there is no analysis of the trends (in the present paper) to see if the assumptions usually involved in a least squares analysis are in fact true (although the authors may have left this out for lack of space). The least squares derivation which is presented in the appendix is quite conventional for models which are linear in the empirical parameters. (In order to describe an arbitrary distribution, more than the mean and standard deviation are generally necessary. In some cases, the simplest description is just the empirically observed distribution itself.)

All in all, this paper is a valuable contribution to the field of circuit reliability. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1382
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Establishment of inherent component reliability

AUTHOR: Allan F. Proske, Bell Telephone Laboratories, Murray Hill, New Jersey

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 139-141

PURPOSE: To show how to update failure-rate tables using data gathered from systems in the field.

ABSTRACT: If the constant failure rate assumption is made, if there are some reasonable criteria for the failure of a part, and if there is a basis for converting field failure rate to inherent failure rate, then the tables of failure rate can be compared to field experience. The tables can be revised as necessary. This paper presents a method of updating the values of inherent failure rates through the analysis of data gathered from systems in the field. In this analysis of feedback data, the tabled values of inherent failure rates are assumed to be correct. The inherent failure rate is converted to an expected failure rate for the particular system, which in turn is converted to an expected number of failures, also assumed to be correct. Limit values are then constructed around this calculated number of failures, to bound the range of number of failures that would be expected in the system. (In the paper, an interval of 95% based on the Biometrika table "Confidence Limits for the Expectation of a Poisson Variable" was used.) The observed number of components replaced is then compared to this interval. If the observed number falls within the interval, the tabulated value is accepted; otherwise the tabulated value is subject to question, and additional investigation is made. This investigation may involve the use of engineering analysis of the circuits and component application in a search for possible causes for failures which might have been overlooked in the original analysis. Examples are given. (Author in part)

REVIEW: The term "inherent" failure rate is perhaps unfortunate; something like "reference" failure rate would be more accurately descriptive and less misleading. But its use is widespread and presumably everyone knows what it means.

There is some magic in the approach described here, all of which is concerned with translating the three "if's" (see ABSTRACT) into reality. Nevertheless, the method has merit, not the least of which is its relative simplicity. For very low failure rates, it may be the only feasible way. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1383
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Performance and reliability of wrapped and potted Mylar capacitors

AUTHOR: D. F. Schmidt, General Electric Company, Hudson Falls, New York

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 142-149

PURPOSE: To present an analysis of a four-year life-testing study of Mylar capacitors made by The General Electric Company.

ABSTRACT: The results of almost 40 million hours of testing of wrapped and potted Mylar capacitors are reported in this paper. Much of the data resulted from testing against MIL-C-27287(USAF). A Poisson distribution has been assumed for the number of failures. Both catastrophic and drift failures are defined and are reported separately. The first group of tests was for 250 hours at 125°C and 1.4 times rated voltage; a failure rate of 0.6%/1000 hrs (upper 90% confidence limit) was demonstrated. The second group was for an average test time of 18,500 hours at 125°C and rated voltage; a failure rate of 0.076%/1000 hrs (upper 90% confidence limit) was demonstrated. A third test was for 33,000 hours with a matrix of temperatures (45°C, 85°C, 125°C) and voltages of 1/2, 2/3, 1, 4/3, 3/2, 2, 8/3, 3, 4, times rated voltage. The failure rate demonstrated by these tests depends on the voltage, temperature, and life behavior that is assumed. Under a common assumption (5th power for voltage, 20°C doubling temperature) the demonstrated failure rate was 0.0038%/1000 hrs (upper 90% confidence limit) at 125°C and rated voltage.

The failure rate as a function of voltage and temperature is not known exactly. It is a function of the type of capacitor and the manufacturing methods. The power law and doubling temperature rules of thumb are inadequate models. It is possible that these capacitors exhibit a decreasing failure rate during the latter part of their lives.

REVIEW: This paper is largely a presentation of data. The interpretations seem adequate and sound. The comments on life as a function of temperature and voltage are most appropriate. The decreasing failure rate speculation may be based as much on hope as on the data since there were too few failures to "prove" anything. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1384
Code 782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component evaluation at $77^{\circ}K$

AUTHORS: J. S. Hildum, E. C. Niehenke, and R. J. Allen, Electronic Systems and Products Division, Martin Company, Baltimore 3, Maryland

SOURCE: Proceedings 1963 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1963, pp. 150-157

PURPOSE: To evaluate the behavior of various brands of resistors, capacitors, transistors, and diodes at $77^{\circ}K$.

ABSTRACT: This paper gives details of the low temperature performance of several different makes of resistors, capacitors, transistors, and diodes. The resistors were subjected to thermal shock, and power handling tests after resistance tests had been performed at room temperature and $77^{\circ}K$ (temperature of liquid nitrogen). The capacitors were tested for capacitance changes between room temperature and $77^{\circ}K$, changes in dissipation factors, and high voltage breakdown. Transistor operation at $77^{\circ}K$ was found to be characterized by little or no gain, except for the field effect transistors in which the gain increased. The most important effect found with the silicon diode was a decrease by a factor of 4 in the dynamic forward resistance at $77^{\circ}K$. Zener diodes operated at $77^{\circ}K$ within the manufacturers' tolerances. With the tunnel diode tested it was found that the maximum peak-to-valley current ratio increased at the low temperature; other significant changes are listed in the paper.

REVIEW: The operation of conventional electronic components at liquid nitrogen and liquid helium temperatures is a fascinating subject which warrants detailed theoretical and experimental study; the authors have, in effect, made a preliminary study, but much remains to be done.

The paper is of general interest but is not too important from the viewpoint of the reliability engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1385 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Secondary breakdown in transistors

AUTHORS: H. Melchior and M. J. O. Strutt, Department of Advanced Electrical Engineering, Swiss Feder. Institute of Technology, Zurich, Switzerland

SOURCE: Proceedings of the IEEE, vol. 52, pp. 439-440, April, 1964, (correspondence)

PURPOSE: To present a model of intrinsic conducting secondary breakdown.

ABSTRACT: Secondary breakdown of reverse biased p-n junctions begins when a localized region of the junction reaches a critical temperature --the temperature at which the intrinsic carrier density n_i is equal to the impurity concentration of the less heavily doped side of the junction. Once this temperature is reached, an intrinsic conducting zone and eventually a molten spot is formed which short circuits the space charge region of the p-n junction so that only the spreading resistance of the bulk n- and p-type regions limit the current flow and determine the sustaining voltage drop observed in secondary breakdown.

The procedure for calculating the critical temperature is to determine the space charge layer doping density from empirical breakdown data and to find the temperature at which n_i is equal to this value. This is the critical temperature and is shown to agree reasonably well with experimentally measured values of runaway temperature for several silicon and germanium devices. A trigger time--the time a pulse of given power needs to trigger the secondary breakdown--is also plotted for the MM 1613 silicon n-p-n transistor.

REVIEW: The second breakdown discussed in this correspondence is evidently initiated from avalanche conditions of a single junction. Although this is not a prerequisite for second breakdown as described by others in which transistors operating in high current, low voltage modes also exhibit second breakdown, it was chosen by the authors as being the best operating mode for the experimental determination of secondary breakdown temperature. The conclusions reached here presumably are applicable to second breakdown from both avalanche and non-avalanche modes of operation.

The existence of a calculable starting temperature for second breakdown that is demonstrated in this communication emphasizes the fundamental nature of the second breakdown phenomenon. The model described does not depend explicitly upon defects or imperfections and should be applicable both to ideal, defect-free units as well as to real, imperfect junctions. This neat result

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

is achieved by determining the space charge doping densities from breakdown voltage measurements which apparently detect and account for the important breakdown-inducing defects in real junctions.

The thermal mechanism of second breakdown described here is similar to that described previously by J. Tauc and A. Abraham [1] and later by English [2], and by Scarlett et. al. (see the paper covered by Abstract and Review Serial Number 1370 and also [3]). (Scarlett considers only transistors--not single junctions.) But the real contribution is the recognition of a simple, direct measurement of a particular junction's susceptibility to second breakdown. A direct consequence of this work is the conclusion that junctions with low breakdown voltage have a higher second breakdown "trigger" temperature (critical temperature) than junctions with high breakdown voltage.

REFERENCES:

[1] J. Tauc and A. Abraham, "Thermal breakdown in silicon p-n junctions," Phys. Rev., 108, 936-937, November, 1957

[2] A. C. English, "Mesoplasmas and 'second breakdown' in silicon junctions," Solid State Electronics, vol. 6, September/ October, 1963, pp. 511-521

[3] R. M. Scarlett and W. Schroen, "Localized thermal effects in silicon power transistors," Physics of Failure in Electronics Volume 2, edited by M. F. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 285-303 (See Abstract and Review Serial Number 1461) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1386
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability concepts applied to knitted mesh RFI gaskets

AUTHOR: A. H. Cohen, Metex Electronics Corporation, Clark, New Jersey

SOURCE: Electromechanical Design, vol. 7, December, 1963, pp. 30-32

PURPOSE: To present suggestions for gasket designs which should lead to more effective, simplified, economical, and reliable shielded enclosures.

ABSTRACT: This article deals with the choice of suitable RFI shielding materials applied with proper mounting pressure and with due consideration of installation methods to prevent damage to the gasket and the equipment being gasketed. The criteria for reliable gasket design are discussed and include: proper material choice, adequate pressure provisions, and redundancy of critical gasket requirements. The criteria for reliable gasket application are discussed and include: safeguards against misuse of gasket, prevention of damage to gasket, prevention of damage to equipment being gasketed, and reusability considerations.

REVIEW: This is a well-written article which contains worthwhile suggestions for gasket design and use. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1387
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interference control in receiver design

AUTHOR: Robert L. Collard, Sparton Electronics, Division of Sparton Corporation, Jackson, Michigan

SOURCE: Electrical Design News, vol. 9, March, 1964, pp. 88-93

PURPOSE: To point out the need for an interference control plan at the conception of a project and to present a method for implementing such a plan.

ABSTRACT: This article discusses radiated interference and conducted interference and their effects upon units of a system. Intermodulation effects, undesired signal effects, and cross modulation effects are described. The need for an interference control plan is presented and a method for including an interference control monitor in a program is illustrated. Several probable trouble areas in interference control are highlighted and techniques for minimizing equipment susceptibilities are discussed.

REVIEW: This is a semi-technical article which is primarily designed to emphasize the need for an interference control plan at the inception of a project. The author's central plan is a good one and is adaptable to any size of project. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1388
Codes 711;712;773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Axial fatigue testing of sheet metals down to -423F

AUTHORS: R. D. Keys and F. R. Schwartzberg, Denver Division, Martin Company

SOURCE: Materials Research & Standards, vol. 4, pp. 222-224, May, 1964

PURPOSE: To describe techniques and apparatus for axial fatigue tests of sheet materials down to liquid hydrogen temperature.

ABSTRACT: The techniques and apparatus described in this paper were designed for axial rather than bending loading because it is easier to calculate the stresses and the method is more representative of particular service conditions. It has the capability of full tension-full compression loading for sheet materials, which is unusual. It is designed for use with a fatigue machine such as the Baldwin SF10U with a capacity of approximately 5000 lbs. (Details of the construction and liquid level control--liquid nitrogen and liquid hydrogen--are given.)

Fully reversed loading for sheets 0.1 inch thick has been obtained. Two sets of curves are shown: one for 5456-H343 aluminum alloy and the other for Ti-5Al-2.5Sn alloy.

REVIEW: This type of work is important in determining the reliability of parts which must operate at cryogenic temperatures. While few data are given here, the article can give an awareness of cryogenic fatigue testing and its importance for designers. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability reporting--an integrated reliability data center

AUTHOR: Eugene Kirby, AiResearch Manufacturing Company of Arizona, Phoenix 34, Arizona (present affiliation: General Electric Company, Computer Department, 13430 North Black Canyon Highway, Phoenix, Arizona)

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 61-68

PURPOSE: To describe a technique for the gathering and use of performance information.

ABSTRACT: Effective data collection is essential to a good reliability program. Many specifications covering reliability requirements in defense and space contracts place emphasis on a failure data system as the core of a reliability program. This paper is concerned with the planning and implementation of such a system. The following aspects are considered:

Sources of Data
Standardization and Reduction of Data
Presentation of Data
Analysis of Data and Corrective Action

The need for and value of an integrated reliability data center are discussed.

REVIEW: Effective data collection is undoubtedly important to reliability analysis. This paper is a brief discussion of some of the fundamental aspects of the problem. Adaptations of the ideas to meet the needs of specific programs should be worthwhile. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1390
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A typical failure mode analysis

AUTHOR: Irving Quart, Reliability Section, Research and Development Division, Hughes Aircraft Company, Culver City, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 69-75

PURPOSE: To describe and illustrate a method for performing a failure mode analysis.

ABSTRACT: Every good designer, in addition to designing for required operation, designs to prevent failure. The latter requirement is usually a tradeoff against cost, weight, etc. The failure analysis as performed by the designer is usually not recorded and is performed in a vague manner. The use of a formal document, such as illustrated in this paper, provides a methodical procedure which becomes part of the visual history of the design.

Failure mode analysis consists of predicting the observable reaction of an item to a failure within it, and the interactions between the item failure mode and the functional requirements which the item must meet. The basic procedure can be used to analyze any phase of a design to study the interactions of several elements. Complete systems may be analyzed using subsystems as the interacting elements; and going down the ladder, subsystem units, subassemblies, individual circuits and even individual piece parts. The equipment studied may be either electronic, electromechanical or fully mechanical. For simplicity this paper is limited to a minor electronic subassembly.

A step-by-step method for performing a failure mode analysis is given. The procedure is illustrated with a simple transistorized DC to DC converter used in a TV camera auxiliary unit. Benefits obtained through the use of the method are listed. (Author in part)

REVIEW: The outlined procedure appears quite reasonable, and its use should result in the benefits which the author has cited. Its actual effectiveness in any particular situation will obviously depend on the validity of the input information (component failure rates, derating factors, ways in which components may fail, etc.). In addition, it is likely to become unwieldy if applied to large complex systems; in this connection the author's suggestion of working with subsystems is good, provided interactions and effects on the over-all system are properly evaluated. In any event, the method is a much more realistic approach to reliability estimation than that of depending on a simple parts count. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1391
Codes 813;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Component failure analysis

AUTHOR: Harold O. Story, Failure Analysis Group, Reliability Control Department, General Dynamics/Astronautics, San Diego, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 77-81

PURPOSE: To describe the Failure Analysis Program at General Dynamics/Astronautics.

ABSTRACT: The Failure Analysis Program at General Dynamics/Astronautics plays a major role in achieving reliability in research, development and production programs in the aerospace industry. The Failure Analysis Group analyzes failures occurring in the factory and the field, operates independently of projects, and handles component failures classified by type, e.g. mechanical, electrical, electronic, etc. Coordination of a type of failure is accomplished among the various project offices and cognizant groups. Care is taken to ensure objectivity in the conclusions and recommendations.

Failure analysis includes the following four basic steps: (1) establishment of mode of failure, (2) determination of cause of failure, (3) classification of failure as due to design or to non-conformance to design, and (4) prescription of necessary corrective action. The failure analyst must be familiar with design theory and requirements, materials, processes, and techniques of manufacture, as well as field and laboratory testing procedures. The necessary facilities must be provided, and the program must have strong management support. The failure analysis group, in turn, must demonstrate the value of its services to test conductors, supervision and design groups, as well as to vendors. A flow chart indicating how a failure analysis problem is handled at General Dynamics/Astronautics is presented and discussed.

REVIEW: This is a brief, clearly-written description of the Failure Analysis Program at General Dynamics Astronautics. As such, it should be worthwhile reading for those concerned with similar programs in other companies. It serves also to point up and emphasize the care and attention which failure analysis must receive if adequate reliability is to be achieved. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1392
Codes 841;843;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Closed loop malfunction reporting system

AUTHOR: Joseph S. Meyer, Guidance and Control Division, Litton Systems, Woodland Hills, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 83-93

PURPOSE: To describe the installation and operation of a computerized malfunction reporting system, the problems observed, the solution, and the results of the operation of the system.

ABSTRACT: Even though continuous stress is placed upon preventing defects through design and reliability efforts, the final accomplishments of reliability achievement are made through malfunction reporting and corrective action. This paper describes a malfunction reporting system which is one of a series of closed loop systems used at Litton Systems. The reporting system provides the basis for defect analysis, failure trend analysis, corrective action, product improvement, measurement of the effectiveness of corrective action, preventive maintenance information, and spares provisioning. The system described deals only with failures at systems test and field operations.

The basic design of the malfunction reporting form is discussed and illustrated, and the importance of transmitting accurate and complete failure information is emphasized. The screening of malfunction reports and the flow of data through the computer system are described. Malfunction report summaries and corrective action requests are illustrated.

REVIEW: As the author has pointed out, failures are inevitable. Systems such as the one described in this paper provide effective means of recognizing failure modes, identifying failure causes, and implementing corrective action. The material in the paper is clearly and graphically presented, and should be quite helpful to those concerned with setting up a malfunction reporting system.
##

Serial Number 1393 -1
Codes 520;715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design of experiments for space radiation evaluations

AUTHORS: I. Doshay and W. F. Emrich, Space-General Corporation, El Monte, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 95-105

PURPOSE: To describe the design of experiments for the determination of the behavior of tantalum capacitors when subjected to radiation in a vacuum environment.

ABSTRACT: Two significant evaluations were made involving film resistors and tantalum capacitors. These involved factorially designed experiments in combined vacuum-gamma-radiation environment. Significant results were obtained from both evaluations and provided data not obtainable from any other sources. The most recent of these tests involved dynamic performance characteristics of Sprague solid tantalum capacitors with 128 samples of four capacitor values at two voltage ratings operating under load, at four voltage levels, within the combined environment of various levels of gamma radiation and, at the same time, in a vacuum chamber. Periods of exposure equivalent to a large number of years (up to approximately a hundred years) are simulated through use of a 10-kilocurie cobalt-60 gamma radiation source.

Significant among the latest findings from the tantalum capacitor evaluation is the relationship of the voltage across the capacitor to the degradation effects reflected in dissipation factor, capacitance deviation, and leakage, all of which were monitored in the test. Apparently, this relationship had not heretofore been uncovered. Its importance lies in the fact that it opposes the general reliability concept of derating capacitors for long life, since, in evaluation, those capacitors which were operated at 100 per cent ratings reflected lower degradation and catastrophic effects than those operated at 50 per cent rated voltage.

Various aspects affecting the design of the experiments are discussed. Some of the characteristic plots obtained from the data developed in the tests are given. Nine pertinent references are cited. (Authors in part)

REVIEW: This paper is a contribution to the knowledge of the effects of the space radiation environment on components. The material is clearly presented in reasonable detail. It should be helpful to those who are concerned with the design of electronic systems to withstand the effects of the space environment. The comments

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

on derating philosophy are very important and reflect the general caution that should always be used--make sure that the derating will actually improve the life of the equipment.

For listings of Abstracts and Reviews of papers on the effects of radiation and other environments see Reviews Serial Numbers 821 and 1280. Other papers bearing on this subject have been covered by Abstracts and Reviews Serial Numbers 1343, 1346, 1354, and 1356. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Modern advances in sampling techniques

AUTHOR: Harry G. Romig, Leach Corporation, Los Angeles, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 107-118

PURPOSE: To describe the sampling techniques available for measuring quality and reliability.

ABSTRACT: Current demands require meaningful data of sufficient quantity to enable designers to reorient their thinking and increase the life and reliability of parts, components, assemblies and systems. The purpose of these data is to secure better measures of quality and reliability and increase the confidence level, the degree of belief that these results are valid. Ways to secure the maximum benefit from such measured results is contrasted with the use of purely attributes data. Statistical methods for checking compatibility of results, significant difference between sets of data, and particularly paired results provide practical methods to increase the reliability and availability through preventive maintenance of products used currently or stored for future use. The nature and number of samples required to provide satisfactory evidence of improvements in quality and reliability are presented together with means for determining confidence levels associated with various quality levels. Reliability relations are provided in line with the most recent mathematical developments in this field. Equations for determining probability values based on small samples inspected and tested by the method of variables rather than the method of attributes are developed to cover non-parametric distributions for worst-case analyses using the Tchebycheff and Camp-Meidell inequalities. Examples presenting their use show their practicality.

Cases where only a few units constitute a lot, as contrasted with a large number of units in a lot, must be handled mathematically and statistically in line with the best techniques of Operations Research to secure optimum benefits. It is necessary to secure the utmost from costly types of data, such as missile firing, sending space vehicles into orbit, and complex systems of all types. Means of utilizing these data to the greatest advantage are given. These recent techniques that utilize all available information are dependent upon meaningful shop data and classification of units into good, questionable, and bad products. A review is made of the use of the trinomial distribution in both attributes and variables inspection methods for these cases since previous papers, such as those on discovery sampling, indicate considerable savings by this approach. Recent work already

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

presented in these areas is augmented by somewhat more sophisticated techniques making use of destructive life testing data and non-destructive short-run AOQL data. These improvements in selecting and evaluating samples provide the desired confidence in results in a shorter time at less cost. Possible unreliability, or lack of reliability, and its relation to the usual failure rates must be treated more exactly. Emphasis must be given to methodologies that provide more assurance that desired goals for reliability and confidence levels may be attained within reasonable time spans. The approach proposed for high-reliability relays is a new approach worth considering. (Author)

REVIEW: This is a good description of the sampling techniques pertinent to quality and reliability. For those who may desire more details, 11 references are cited. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1395
Codes 824;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimation of the reliability of complex systems

AUTHOR: K. T. Wallenius, Stanford University, Stanford, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 119-122

PURPOSE: To survey the general area of estimating system reliability on the basis of subsystem tests.

ABSTRACT: The general problem of estimating system reliability is discussed; point estimates and interval estimates are distinguished. The system considered is composed of independent subsystems. Given estimates of the subsystem reliabilities, it is desired to determine a confidence interval on the reliability of the system. The methods available for doing this are surveyed; pertinent references are cited. A table of lower confidence limits for the reliability of a system composed of three dissimilar subsystems in parallel is given as an example.

REVIEW: The estimation of system reliability from the results of tests on subsystems or components is important. The problem deserves more attention than it has received. This paper is a survey and interpretation of some of the work that has been done; it contributes nothing new to the solution of the problem. Other papers addressed to the topic of confidence limits on system reliability have been covered by Abstracts and Reviews Serial Numbers 152, 227, and 752. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1396
Codes 720;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor process control through failure analysis

AUTHOR: Ralph L. Auer, Advanced Technology Laboratories, Division of American-Standard

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 161-168

PURPOSE: To describe a failure analysis program on transistors, and to outline some of its achievements.

ABSTRACT: This paper describes the failure analysis program implemented by one transistor manufacturer to improve product quality and reduce scrap losses of silicon mesa and planar transistors. The failure analysis effort is detailed from the planning phases through execution of the program; specific accomplishments are cited.

The following are cited as lessons learned during the failure analysis program:

1. A failure analysis program should be well planned prior to its implementation.
2. Members of a failure analysis program should be trained by qualified personnel at the start of the program. A failure analysis committee should include representatives from the Research and Development activity to continue this training.
3. A failure analysis committee must make every attempt to be completely objective in drawing conclusions. Criticism of a product implies criticism of the person responsible for the product and this must be accomplished as tactfully as possible.
4. A failure analysis program, well planned and implemented, can result in increased device reliability, decreased scrap loss, and a greater quality awareness throughout the company. (Author in part)

REVIEW: As a reasonably-detailed description of the experience of one transistor manufacturer with a failure analysis program, this paper should be of interest and value to others who have similar problems. As the author has stated, the paper does not constitute an effort to describe all of the possible failure modes in silicon mesa and planar transistors. Several references on this topic are cited. References 2,3, and 4 in the paper have been covered by Abstracts and Reviews Serial Numbers 233, 596, and 704 respectively. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1397
Codes 815;816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Subcontractor monitoring

AUTHOR: John de S. Coutinho, Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 215-224

PURPOSE: To discuss reliability control of suppliers as an important problem in the achievement of reliability improvement in aerospace systems.

ABSTRACT: Subcontractor monitoring is discussed as one of the most important current problems in reliability control. Deficiencies of present procurement practices are highlighted for new high cost, low volume, single source items developed on a tight rigid schedule. Airframe and engine manufacturers, due to their concern with airworthiness and safety of life, have developed successful techniques dealing with these problems which are being adapted to apply to other items. The approach is being proposed by Grumman for use on the Lunar Excursion Module (LEM) of Apollo and the Grumman portion of the Interservice Tactical Fighter TFX.

The importance of testing devices to failure under judicious combinations of systematically increasing environmental stresses is indicated. Series of tests to failure should be conducted for at least two points in time. It is recommended that in new developments the inherent reliability should be demonstrated before qualification testing is begun. It is proposed that, through careful planning, the maximum amount of data should be obtained from all testing, minimizing the number of tests performed purely for reliability demonstration. The importance of good specifications is discussed. (Author in part)

REVIEW: This is a good general discussion of the major problems in the procurement of subcontracted items of desired reliability. As such it will be of interest to general contractors faced with these problems. The implementation of the ideas and suggestions in specific situations is likely to require careful attention and considerable effort. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1398
Code 851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determining weapon system reliability from missile firings

AUTHOR: Edwin H. Johnson, Missile Evaluation Department, U. S. Naval Ordnance Laboratory, Corona, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 241-244

PURPOSE: To discuss some of the difficulties encountered in determining missile reliability from actual firings rather than from theoretical studies or computer simulations.

ABSTRACT: It is desirable to determine the reliability of missile weapon systems from the results of actual firings using tactical equipment. Some of the difficulties encountered in making this determination are (1) the small number of firings during a year, (2) the question of combining data from separate firing facilities using similar equipment, and (3) assigning failures to the proper subsystem or component. Results from hypothetical firings are presented. Evaluations of these firings are made and a method of estimating reliability when the number of undetermined ratings is large is given. (Author)

REVIEW: This is a very brief paper, and the points made are not new or surprising. In view of the high cost of complete missile systems, it is not feasible to make many firings purely for the purpose of demonstrating reliability. Thus methods based on theoretical studies, computer simulations, and knowledge of the behavior of subsystems and components are likely to be more widely used. Sound ways of incorporating such data as are available from actual firings would be very valuable. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1399
Codes 300;610;800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: QC, OR and Reliability

AUTHOR: Paul S. Olmstead, Lockheed Electronics Company, Clark, New Jersey

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 245-249

PURPOSE: To trace the evolution of quality control from its inception as a procedure for maximizing quality for minimum cost to its present status as a basis for operations research and reliability evaluation.

ABSTRACT: Referring to an earlier publication, the author describes "an operational view of quality control" applicable to a particular product as including the following steps:

1. Determine the quality that is wanted through consumer research,
2. Perform research and development work to devise means for fulfilling these wants at a reasonable cost,
3. Design and specify the product selected and in so doing set tolerance limits,
4. Make the product that is specified,
5. Inspect the product for conformance to design and specification, and
6. Test the product in service (operational research) to see that it satisfies the wants of the user in an adequate, dependable and economic way.

It is indicated that quality control must include a great deal of operations research. To this there has been added in recent years an interest in reliability. The result has been to change the concept of the economic state of statistical quality control desired. Quality control must provide for adjustment to a new state of the art so as to keep quality and cost in economic balance. It is suggested that the real aim of reliability is perfection. A quality control procedure for monitoring approach to this objective is outlined. (Author in part)

REVIEW: This paper is essentially a discussion of background material forming the basis for the paper by the same author covered by Abstract and Review Serial Number 1194. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1400
Codes 814;817;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A resource allocation model for the quality control manager

AUTHOR: Irvin R. Whiteman, C-E-I-R, Inc., Los Angeles Center, 9171 Wilshire Boulevard, Beverly Hills, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 265-271

PURPOSE: To propose a resource allocation model to reflect current and future estimates of the reliability of equipment and to permit evaluation of the best policy for the accomplishment of given objectives.

ABSTRACT: The quality control manager is interested in determining the effectiveness of those efforts expended in defining, controlling and improving quality output, and is interested in obtaining recommendations for improved effectiveness. A resource allocation model is proposed which reflects current and future estimates of reliability of the equipment, its systems and subsystems, and permits an evaluation of the best policy to pursue to accomplish a given set of objectives. In addition to the knowledge of the current reliability status of the equipment, it is of prime interest to know the future reliability of the equipment as a function of time. This may be obtained by using the resource allocation model in conjunction with the reliability reporting system. It is possible to answer questions of the following nature:

1. What is the probability that the equipment will possess a given reliability at a given time?
2. What period of time is required to achieve some desired equipment reliability? (Author)

REVIEW: The basic idea of this paper, namely that of combining initial estimates with data obtained from unfolding operational experience in order to predict future reliability, is good. However, the paper provides little detail on how this is actually to be done. For example, at one point the statement is made that "The proper formula to obtain the expected reliability must be derived, but it is possible that it may be of the following form ...." The form given is a weighted average of three reliability estimates: an optimistic estimate, a most likely estimate, and a pessimistic estimate, in which the most likely estimate is given a weight four times that of each of the others. There is no discussion of the criteria to be used in arriving at a particular weighting. It would seem also that a considerable amount of subjective judgment would have to be used in arriving at values of the three estimates. Thus while the basic idea is good, the presentation has less value to the reader than if it had contained more of the detail needed for proper interpretation and application. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1401
Codes 224;760

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The explanation and use of truncated sequential life acceptance tests

AUTHORS: Leo A. Aroian and Henry Matosoff, Reliability Staff, Electronics Division, Space Technology Laboratories, Inc., Redondo Beach, California

SOURCE: Transactions Tenth Annual Western Region Conference sponsored by the San Bernardino Section of the American Society for Quality Control, Las Vegas, Nevada, February, 1963, pp. 329-340

PURPOSE: To explain truncated sequential life acceptance tests, show how to use them, and give some examples and a short set of tables.

ABSTRACT: Formulas for truncated sequential tests based on the exponential density function have been derived by the first author (see Abstract and Review Serial Number 997). Tables for use in performing such tests have been published by Space Technology Laboratories; references to these are cited in the present paper. This paper gives detailed illustration of sequential life acceptance tests in use and further explains in quality control language methods of using the STL tables.

REVIEW: As indicated in the ABSTRACT, this is essentially a companion paper to the one covered by Abstract and Review Serial Number 997. The theory was developed in the latter; this paper presents an interpretation for the user. It accomplishes its stated purpose very well. ##

Serial Number 1402 -1
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The NASA 200 Series quality publications

AUTHOR: Jack A. Baer, Chief, Saturn SII Branch, Quality Assurance Division, National Aeronautics & Space Administration, Downey, California

SOURCE: 4 pp., presented at a One Day Symposium, Phoenix Section, American Society for Quality Control, Phoenix, Arizona, April 13, 1963

PURPOSE: To review the National Aeronautics and Space Administration Quality Publications NPC 200-1, -2 and -3.

ABSTRACT: NASA recognizes the need for a "Space Age" approach to quality and reliability requirements, and has issued Quality Publications NPC 200-1, -2 and -3, which are designed to help the contractor and the government inspector in producing the highest quality space vehicles. These documents have been incorporated into recent NASA Contracts: NPC 200-1 is for use by the government inspector, -2 governs prime and subcontractors who have design responsibility on complex products, and -3 is a short publication covering minimum requirements for inspection systems on suppliers of parts and materials. These three documents are reviewed and discussed.

REVIEW: These quality publications reflect NASA experience on numerous space programs. They can serve to improve the reliability and quality of space program equipment, being limited in their effectiveness only by the collective knowledge and intentions of the contractors and government procurement personnel. This paper could be of interest to those doing business with NASA.

The comment is made that there is neither time nor money for the conventional reliability test program, which is outmoded on space programs. Presumably in referring to the conventional reliability test program the author has in mind life tests with a statistical interpretation of the time-to-failure results, as described in the AGREE (Advisory Group on the Reliability of Electronic Equipment) report. It is questionable if this type of test is either generally conventional or outmoded. Although the AGREE type of test has received considerable discussion and has been included on many DOD agency initial requests for proposals, it has actually had limited implementation. Further, this testing concept may well be basically inapplicable to complex space programs, as are other testing, manufacturing, or design concepts. This does not mean that a life testing concept is outmoded; it may well be suitable for increased application on less complex products.

In a private communication replying to the above, the author has made the comments quoted below.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

"My point on reliability testing was that we used to build an article with minimal Quality Assurance control and then life test it to prove its worth. Prior to the Space Age, with its accelerated programs and high cost of end items for testing, this worked fairly well. Now, we feel it is better to define rigid quality and reliability requirements prior to procurement.

Systems, components and parts are classified by their level of criticality, depending on failure mode effect analysis. From this, quality and reliability requirements are defined for both "in-house" and supplier programs. These requirements include several Design Reviews between the suppliers and the prime contractor development, acceptance, qualification, and reliability testing programs which result in a level of confidence prior to testing in the flight vehicle.

On very critical and high cost programs we negotiate with other government agencies to perform Quality Assurance functions in accordance with NASA Quality Publication NPC 200-1. We are receiving good support from the other government agencies in all phases of Quality Assurance, including Reliability and Qualification Testing." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quality and reliability resources needed to compete for aerospace business

AUTHOR: Leslie W. Ball, Director of Reliability, Aero-Space Division, The Boeing Company, Seattle, Washington

SOURCE: 10 pp., presented at a One Day Symposium, Phoenix Section, American Society for Quality Control, Phoenix, Arizona, April 13, 1963

PURPOSE: To present a management system that will satisfy modern requirements of input contracting.

ABSTRACT: This paper is addressed to management personnel in those companies that are now seeking to supply the multi-billion dollar aerospace industry. It provides an analysis of recent changes in the buyers' needs and in the buyer-seller relationship. The principal change is that it has become necessary to buy certain input disciplines as well as end products. These disciplines include reliability, value engineering, quality assurance, and materiel management. A management system for developing, applying and selling these disciplines is discussed and illustrated. This system involves the inclusion of assurance functions for each of the four major project phases of program, design, manufacture and use. (Author in part)

REVIEW: The position is taken in this paper that in order to avoid delay resulting from the seller failing to produce in accordance with specifications, it is necessary for the buyer to place requirements on how the seller produces his product as well as placing requirements on what the product is. The activities of a seller which comprise an acceptable approach to production are described in terms of such concepts as experience retention, critical activities, and input compliance. Apparently these are somewhat unique terms used to describe modern concepts of what is generally referred to as product assurance, which encompasses such areas as reliability, quality, and value. The viewpoints expressed in this paper would be of interest to those doing business with the author's company.

In order for the concept of input contracting to actually avoid delays the buyer must be correct in the activities which he forces to occur. The buyer can end up purchasing an extensive reliability or other input activity program which actually makes no effective contribution, but is costly and creates confusion. For a buyer to input contract effectively is a stringent requirement, calling for extensive talents which at times seem to be lacking in a buyer's control personnel. The author's position is that by using the seller's own procedures, the concept of input contracting can be effectively implemented. Here the buyer initially approves

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

the seller's own procedures, and throughout the program assures that they are followed. The concept of significant financial incentive contracting that is not cited in this paper could also be considered as an alternate or joint means of insuring that the seller produces in accordance with specifications without delay. This viewpoint appears to be finding increased application to reliability and quality requirements as well as to the schedule, performance, and cost areas. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1404
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Navy analysis of such reliability specifications as MIL-R-27542

AUTHOR: B. C. Milroy, Quality Assurance Specialist, Technical Procedures Staff, Quality Assurance Department, Inspector of Naval Material, Los Angeles, California

SOURCE: 5 pp., presented at a One Day Symposium, Phoenix Section, American Society for Quality Control, Phoenix, Arizona, April 13, 1963

PURPOSE: To provide a review and discussion of reliability specification MIL-R-27542 based on the author's observations of experience on Navy Material Reliability Programs.

ABSTRACT: The contents of MIL-R-27542, Military Specification on Reliability Program Requirements for Aerospace Systems, Subsystems, and Equipment, are reviewed with emphasis on required procedures of the reliability program. The author feels that this specification is an excellent example of a complete reliability program that reflects modern principles of reliability. Caution is recommended to bidders in areas with significant cost implications, as data submittal and reliability demonstration testing. The Navy failure and reliability data feedback systems for the field and fleet are briefly described. Highlights of present problems of implementing reliability programs are cited.

REVIEW: The military specification MIL-R-27542 has been receiving wide application in the Department of Defense. It does reflect significant experience with reliability programs. This paper would be of interest to bidders responding to a Naval procurement implementing this specification.

The contents of the paper are more in the nature of personal observations of the author, rather than a broad and policy-level Naval position as the title might imply.

For additional remarks on this specification see Abstract and Review Serial Number 1202.

In a private communication commenting on the above, Mr. E. L. Sowman (Acting Director, Quality Assurance Department, Inspector of Naval Material, Bldg. 71, 190th & Normandie, Torrance, California 90509) has pointed out that the Navy has progressed beyond MIL-R-27542 by the introduction of a specification identified as WR-30 which combines reliability and maintainability. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An optimum cost/reliability program for missile and spacecraft parts

AUTHOR: William E. Wagner, Chief, Parts Reliability Control, Motorola, Inc., Military Electronics Division, Western Center, Scottsdale, Arizona

SOURCE: 9 pp., presented at a One Day Symposium, Phoenix Section, American Society for Quality Control, Phoenix, Arizona, April 13, 1963

PURPOSE: To present a parts reliability program devised for today's reliability and financial atmosphere.

ABSTRACT: A parts reliability program was devised with the objective of providing high-reliability parts, free of defects, with less delays to schedule, and at a lower cost than under existing programs. This program is vendor-oriented, attempting to avoid arbitrary and high cost burdens on the vendor which do not yield appropriate returns of increased reliability. It emphasizes the creation and fabricating of a design, and of processes, that are free of defects. The program includes five basic steps:

1. The use of vendor-supplied normal inspection data as objective evidence of vendor implementation, and to aid in-house incoming inspection procedures.
2. The requirement that vendors adequately control all of the key materials and processes involved in fabrication.
3. The use of special screening tests preferably performed by the vendor for controlling special drift characteristics encountered in state-of-the-art design.
4. The use of results of reassurance environmental testing normally performed by the vendor as further objective evidence.
5. An in-house audit on supplier process control through limited reassurance environmental and dissection testing.

Each of the steps is discussed and explained.

REVIEW: This approach to parts reliability control strives for a balance between the desires of the buyer and those of the seller with a view toward cost consciousness. It reflects experience and sound judgment, which will also be required together with engineering-level talent to implement the program. Unfortunately, little evidence or experience is presented to illustrate that the program actually achieves the objectives of providing high-reliability parts, free of defects, with less delays to schedule and at a lower cost than under existing programs. Little mention is made of such additional areas of a parts reliability program as initial part type and vendor selection and standardization, part procurement drawings and specifications, and part qualification testing; the program presented is apparently associated only with the manufacturing function. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1406 -1
Codes 813;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of requirements in reliability physics

AUTHOR: Alfred L. Tamburrino, Applied Research Laboratory, Rome Air Development Center, Griffiss Air Force Base, New York

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 1-24 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To discuss the necessary kinds of overall planning for an effective failure mechanisms program.

ABSTRACT: From the point of view of impact on complex military systems, a failure physics program will have the greatest value when individual system reliability requirements are reviewed by a competent central source. As is repeatedly pointed out in this discussion, failure mechanism analyses are experimentally and analytically difficult to conduct and require special skills and facilities. While many part manufacturers conduct careful failure mechanism analyses on their specific products, a concerted effort to integrate and correlate the results of these independent efforts is required to determine what can be learned from a generalized analysis and to assure that maximum value is derived from proposed independent efforts.

The advantages of failure mechanism analysis to accelerated testing, screening techniques, and product improvement have been generally recognized, and some system programs have already incorporated failure physics as part of their reliability improvement or assessment program. The recognition that the more complex a system becomes the costlier the penalty for not having parts with adequate high-confidence reliability data early in the program is a lesson that has been learned the hard way.

A determination of the parts which merit particular attention from a failure mechanism analysis may, like other reliability needs, be estimated from part populations and failure rate. Planning the extent and scope of any failure physics effort can benefit from an analysis of the prevalence of failure mechanisms known for each part, as well as from a collective list. In addition to prevalence of failure mechanisms, such factors as measurement techniques, materials, state of technology, and future applicability are important.

Improvement of our knowledge of the nature and prevalence of failure mechanisms must continue, just as the reliability engineer

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

needs to continually improve his knowledge of part failure rates. Many part manufacturers, who have long been exerting effort in failure analysis of their specific products, have information of this type at their disposal. There is a strong need for the collection and analysis of these data, with continuous revision by a central agency. Publication by researchers in industry of failure mechanism and solution is strongly urged. Like any scientific problem, failure physics will advance most rapidly in an open scientific atmosphere. The understandable reticence of manufacturers to divulge details about proprietary processes, as well as to divulge the existence of anything so psychologically negative as failure, will have to be overcome. (Author in part)

REVIEW: This is a general paper and probably intentionally occupies the initial place in the book. It is useful for orientation purposes rather than for specific information. It contains a bibliography organized under the headings: Capacitors (12 items), Resistors (11 items), Transistors and Diodes (12 items), and Measurement Techniques (10 items). While this listing is not an exhaustive bibliography on failure mechanisms in electronic components, it will provide additional detail on some of the points made by the author. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Research toward a physics of aging of electronic component parts

AUTHORS: Ralph E. Thomas and H. Clay Gorton, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 25-60 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To suggest models for analysis of aging and to give examples of their application.

ABSTRACT: The Arrhenius equation is $R = \exp(A-B/T)$, where the constants A and B are presumed to be independent of temperature T and time t, and R is the (assumed constant) time rate of change of a quantity. Hopefully it will be possible to find a quantity, which is some function of the parameter being measured, such that R is independent of time. These expectations can be checked experimentally and the unknown constants can be evaluated by least squares. (Examples are given for resistors and transistors.)

True acceleration of stressing is defined as those new conditions of operation which leave the part in the same condition that it would have been in under a longer period of time at normal conditions. This means that all important degradation modes must cause the same relative aggravation under the two conditions.

The Arrhenius equation is rather empirical and it is possible to derive a different equation from some fundamental concepts. The Eyring model is $R_o = a(kT/h) \exp(-b/T)$, where a and b are constants (predictable in principle from basic theory); k and h are Boltzmann's and Planck's constants. In the usual range of measurements, it is difficult to distinguish empirically between the two equations. It is convenient to add the effects of nonthermal stresses by using a factor of the form $\exp[(C + D/kT)S]$, where S is the stress. The constants in this expression can be determined by least squares if enough data are available.

In order to investigate the effects of temperature and nonthermal stresses on aging, a silicon rectifier was picked and a test condition matrix was designed. So far there has been no aging although some interesting results are apparent from the activation energy data.

REVIEW: This is generally a good paper although the following three points

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS

AND TECHNICAL REVIEWS

are questionable.

1. The definition of true acceleration (paraphrased in the above ABSTRACT) is not equivalent to saying that the Arrhenius model is accurate. This problem deserves further amplification.

2. The Arrhenius model could as easily have been extended to nonthermal stresses as the Eyring model. There is little basic justification given for the choice in the text. Possibly some recourse to thermodynamic concepts such as Gibbs free energy could be used to advantage.

3. The use of a multiplying factor S for a generalized stress is ambiguous. What, for example, does one use for S when the "stress" is a vibration?

It should be emphasized (as the authors point out) that neither the Arrhenius nor the Eyring equation is applicable to all processes. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1408
Code 820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Derivation of Delbruck's model for random failure (for semiconductor materials): its identification with the Arrhenius model; and its experimental verification

AUTHORS: A. V. Pershing and G. E. Hollingsworth, Lockheed Missiles and Space Company, Sunnyvale, California

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 61-67 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To derive the Delbruck model for time of reaction and show its application to failure rate.

ABSTRACT: The derivation of the fundamental Delbruck model (as interpreted by Schrodinger) incorporates generalized basic physical changes depending on a random selection of "states" from the universal entropy relation of chance events, as the states become mixed and disordered in time. The inversion of this model thus obtains the failure rate, λ, as an exponential function of the temperature and the total activation energy, W_1, of a single particle (atomic ion). (Authors)

REVIEW: This paper is difficult to read--perhaps because of its terseness. It is not at all clear what the authors do nor what they are trying to do, although the algebra, per se, appears to be correct.

In a private communication replying to the above, the first author says "Please consult Eddington's masterpiece on the super-mathematician view of nature and group theory in Volume 3 of The World of Mathematics, in which he 'proves' that operator math is not entirely correct until man's mental interpreted picture is completely erased leaving only a hazy smear and the operators. The entropy method is of this type. Applying this model ($\Gamma \cong k \ln D$), where Γ is the entropy, which accumulates with failure, and therefore with time, D being the measure of disorder, indicates that failure with time t as in Delbruck's model assumes the W_1 to represent the enhanced energy needed for an atom (ion) to break away from the normal lattice to act as origin for the tiny microcracks which we assume lead to fracture. Naturally, since the picture (in detail) disappears, we prefer not to try to explain it; it becomes entirely symbolic." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1409
Codes 711;714;820;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Comprehensive failure mechanism theory--metal film resistor behavior

AUTHORS: M. Goldberg, A. Horberg, R. Stewart, and D. Levinson, IIT Research Institute, Chicago, Illinois

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 68-93 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To describe the application of the physics-of-failure approach to the behavior of a metal film resistor.

ABSTRACT: Part 1 describes the experimental activities that have been undertaken to establish certain characteristics of metal film resistors formed from deposited Evanohm (75% Ni, 20% Cr, 2.5% Cu, 2.5% Al), for the purpose of developing a predictive model of parts failure. Dependence of resistance and temperature coefficient of resistance upon the operative physical mechanisms in a temperature environment are considered. Oxidation, precipitation, stress relief and agglomeration are discussed as the most likely causes of first order changes in the properties of interest. Oxidation kinetics are being established by measuring the gain in mass of the film, which is deposited upon a quartz crystal surface. Changes in crystal frequency with temperature and time can be related to a gain in mass of the film. Analyses of actual film composition have been made using an electron microprobe analyzer. The film has been shown to be richer in Cr and Al than the alloy from which it is formed, negating the possibility of applying the characteristics of the original alloy directly in the analysis.

Part 2 postulates mathematical models to describe resistor behavior in terms of the time at which it "fails" by exceeding a set resistance value. A technique is presented for extending such models to take into account the statistical variations that are encountered in practice. Composition and thickness of the film are considered as random variables. The method of moments is used in estimating the parameters of the distribution of times-to-failure; the generalized gamma distribution is assumed.

REVIEW: This work shows the enormous difficulties involved in a comprehensive physics-of-failure approach. The authors have gone into each facet in depth, yet have had to make many "engineering judgments." Hopefully, actual failure rate data for these resistors will eventually be predicted from fundamental knowledge of the materials and processes that go into their making. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1410
Codes 821;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Stress-strength theory and its transformation into reliability functions

AUTHORS: B. Tiger and K. Weir, Radio Corporation of America, Defense Electronic Products, Camden, New Jersey

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 94-101 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To introduce the stress-strength concept of failure.

ABSTRACT: A device, when required to operate, is subject to a set of causes of failure (stresses) C_i, i=1, ...n, each having a probability of occurrence $P(C_i)$, and a set of respective probabilities of failure resulting from each stress (respective strengths) $P(F|C_i)$. Letting R denote the reliability or the probability that all device strengths exceed respective stresses, and assuming independence among the probabilities of strengths exceeding stresses, the mathematical "stress-strength" model is:

$$R = \prod_{i=1}^{n} [1 - P(C_i)P(F|C_i)]. \qquad (1)$$

The $P(C_i)$ terms can be considered stresses, and the $P(F|C_i)$ terms can be considered respective strengths. A device cannot fail unless a stress level exceeds a device strength. Therefore, equation (1) can be considered as a description of the device reliability defined as its probability of operating within specified limits for the time and operating conditions specified. To incorporate time into this statement, one must perform the same experiments on sets of random samples of similar devices after various operating times, and plot the results. The reliabilities can then be estimated from tests to failure, which are much easier than prolonged life tests. (Authors in part)

REVIEW: It is doubtful that the stress-strength concept is adequate to describe all kinds of failure--for example: the clogging of a pipe or the corrosion of a wire. One big difficulty in applying this concept is knowing the actual distribution sufficiently well in the tail region so that high reliability can be accurately estimated. To call probabilities such names as stress and strength, as the authors do, is stretching the language a little too far. While this theory may have some application, its general utility is rather questionable. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1411
Codes 782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Diffusion studies on stressed tantalum-tantalum oxide capacitors

AUTHORS: Neva Johnson and Kenneth Greenough, Motorola Inc., Solid State Systems Division, Phoenix, Arizona

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 103-123 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To describe the effects of electrical and temperature stresses on the tantalum concentration profile in oxide layers formed by anodizing tantalum films.

ABSTRACT: Tantalum films, 3000A thick, evaporated on fused-quartz substrates and activated by neutron irradiation, were anodized at 82 volts to form an oxide layer approximately 1600A thick. Counterelectrodes of gold were evaporated on the oxide and the completed thin-film capacitors were placed under thermal and electrical stress. The radioactive profiles of unstressed tantalum units show a pronounced variation of the tantalum-to-oxygen ratio from that of pure tantalum at the metal-oxide interface to a limiting value 600A away from the interface. Application of thermal and electrical stresses alter the shape of the gradient and extend it several hundred angstroms further into the oxide layer. The data were normalized with respect to the gradient formed by anodization in the unstressed unit. It was then shown that thermal diffusion creates some regions in the oxide near the tantalum interface where the tantalum concentration was depleted below that of the original unstressed unit, and some regions farther away from the interface where tantalum was in excess. Direct-current electrical bias accelerated the tantalum diffusion, and in combination with short-term thermal stress created regions where the tantalum concentration was in excess of that of the unstressed unit. Longer term thermal and electrical stress gave rise to an over-all region of tantalum depletion in the oxide. Diffusion constants calculated as a function of oxide thickness were of the order of 10^{-13} cm^2/day with the larger constants associated with electrically stressed units. (Authors)

REVIEW: In this very well-written paper, the authors describe a careful study of a complex phenomenon. Qualitatively, the report should be of general interest to people working with film interfaces, particularly tantalum-tantalum oxide. It is unlikely, however, that the quantitative results will be very meaningful because of the extreme difficulty of reproducing the systems under different conditions. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1412 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Solid-state thermal diffusion: a contributor to degradation of semiconductor junction devices

AUTHOR: Morris C. Johnson, Burroughs Corporation, Burroughs Laboratories, Paoli, Pennsylvania

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 124-144 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To show that the expected lifetime of any semiconductor junction device can be calculated on the basis of diffusion.

ABSTRACT: The premise is made that metallic impurities diffuse into the bulk semiconductor regions of semiconductor junction devices, within the limit imposed by the solid solubility of these impurities. The subsequent ionization of these "unwanted" impurities causes certain electronic parameters of the junction to be altered in a predictable way; for example, the addition of these ionizable impurities near the physical interface at the junction causes a change in the electronic structure of the depletion layer which is clearly evidenced by shifts in reverse-biased junction capacitance. The capacitive technique of measuring solid-state diffusion is examined and its application to the problem of describing failure in semiconductor junction devices is set forth.

As a first approximation, a simple one-dimensional diffusion model has been proposed, and the equations (Fick, Poisson, and capacitance) consistent with such a model are solved, simultaneously, to yield an expression for junction capacitance as a function of initial resistivities, diffusion constants, bias voltages, and diffusion time. Successive models which have been proposed seem to be more comprehensive, since they take into consideration additional ways in which impurities may be "moved about" in the vicinity of the junction.

In addition to causing a shift in junction capacitance, the diffusion of impurities through the metal-semiconductor interface physically shifts the position of the junction (defined as the point at which the net ionizable impurity concentration is zero) from its original position at the interface into the bulk semiconductor region. Experimentally, this shift may be seen as a reduction in "punch-through" voltages (V_{ceo}) of transistors.

Some of the results of this investigation are compared with field data provided by one vendor and with experimental data collected

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

at these laboratories. At temperatures above 85°C, the agreement is good.

REVIEW: Unfortunately the primary objective of this paper has not been met. While demonstrating that, in germanium surface barrier transistors, diffusion of the metallic contact materials does cause degradation and failure, it is not realistic to extrapolate this information to other devices. Diffusion constants of impurities in silicon planar devices, for example, are orders of magnitude lower than in the example used here. Because of this, failures by diffusion-induced changes are extremely unlikely in most semiconductor junction devices. This work does reveal a basic problem with the surface barrier transistor which has contributed to the obsolescence of this type.

The limited applicability of the results of this work is not enhanced by the procedures used. A number of equations lack dimensional balance. One finds in Equations 8 and 12, for example, charge density and impurity density with apparently the same dimensions. An allusion to "uncovered charges" is made in Figure 3. The nature of an uncovered charge eludes the reader. On page 131 it is indicated that an incorrect method for calculating depletion layer width would be shown. It is not. It was a relief to find in the discussion of the equality of impurity density and charge density with reference to Poisson's equation, that the author did restrict this to the depletion region. For several paragraphs the reader was left in suspense.

This paper cannot be recommended as serving a useful purpose other than demonstrating a modeling application. Some interesting data on parameter distributions in surface barrier transistors are given. Other secondhand information on failure rate of this transistor as a function of temperature is given. Generally, the mathematical derivations are not particularly rigorous and the discussion is at times confusing. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1413
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure mechanism in silicon

AUTHORS: J. E. Mann and N. P. Sandler, Pacific Semiconductors, Inc., Lawndale, California

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 145-153 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To discuss the relationship between diffusion-generated dislocations and bulk cleavage failure along with several modifications which were applied to eliminate this failure mechanism.

ABSTRACT: Impurity diffusion into silicon generates dislocations with density proportional to the impurity concentration gradient. The maximum impurity gradient after a typical phosphorus diffusion occurs at about one-third of the total diffusion depth. To confirm the relationship between impurity gradient and dislocation density, diffused samples were cleaved and Dash-etched to obtain a measure of the dislocation density as a function of depth; other samples from the same batch were diced and subjected to shear tests. It is concluded that: (1) dislocations are generated during phosphorus diffusion into silicon, (2) the distribution of generated dislocations is directly related to the diffused impurity concentration profile, (3) the position of the maximum number of generated dislocations is equal to approximately one-third the total diffusion depth as measured from the surface, (4) with the usual high surface impurity concentration, the generated dislocations form a plane of relatively low mechanical strength at this position, increasing the probability of bulk cleavage failure when the structure is mechanically or thermally stressed, and (5) removal or redistribution in a more random configuration of the generated dislocations eliminates this bulk failure mechanism. (Authors in part)

REVIEW: The data showing the relationship between the diffused impurity profile and the dislocation density are quite graphic and convincing. Conclusions 1-3 can be accepted quite readily, but the conclusions from the shear tests are less obvious. Only one diffused sample sheared differently from the non-diffused sample, so that conclusions 4 and 5 appear to be based on a small amount of data. The "modifications which were applied to the elimination of this failure mechanism" are also not adequately explained. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1414 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some failure mechanisms at insulator-conductor junctions

AUTHORS: G. A. Shirn and D. M. Smyth, Research Center, Sprague Electric Company, North Adams, Massachusetts

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 154-162 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To describe degrading diffusion mechanisms which can occur at interfaces in electronic components, their effects, and a way to minimize them.

ABSTRACT: An electronic component often contains different materials in contact, and since the component has been designed on this basis, any change in the situation will usually be detrimental. An abrupt junction between two different materials is often thermodynamically unstable. The proper provocation, such as elevated temperature or high electric fields, can trigger the relief of the instability.

Anodized tantalum and ceramic barium titanate have been studied with the goal of determining the detailed mechanism by which degradation occurs.

One of the processing steps involved in the construction of a $Ta/Ta_2O_5/MnO_2$ capacitor can lead to unacceptably large dependences of capacitance and equivalent series resistance on temperature, frequency, and dc bias due to reduction of the oxide. At the normally rated temperature and load voltage for these capacitors, there is no significant further reduction of the oxide by the metal. However, the oxygen vacancies, and hence the conductivity, tend to become more homogeneously distributed in the oxide because of the concentration gradient of vacancies and the additional influence of the electric field. This not only decreases conductivity of the conducting region of the oxide, but unfortunately increases conductivity of the most insulating region of the oxide.

Ceramic $BaTiO_3$ when life-tested to breakdown changes color from light tan to blue or blue-black. It is proposed that these color effects are caused by the presence of oxygen vacancies injected by the anode. The presence of the vacancies increases the conductivity of the device. One remedial step is to reduce the number of vacancies. A metal ion of higher valency bismuth was substituted for some of those in the host crystal in the grain boun-

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

dary region to lower the concentration of oxygen vacancies. The result showed an improvement by at least an order of ten for the aging characteristics of the bismuth-treated ceramics.

REVIEW: This is a good brief discussion of an important failure mechanism, i.e., diffusion at material interfaces. Processes which apparently occur in tantalum capacitors and in barium titanate are supported by the data given. The solution presented for $BaTiO_3$ in order to suppress oxygen vacancy diffusion is reasonable. More work of this type is needed in failure mechanisms studies. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1415 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Silicon transistor failure mechanisms caused by surface charge separation

AUTHOR: E. David Metz, Motorola, Incorporated, Semiconductor Products Division, Phoenix, Arizona

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 163-172 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To explain a specific type of transistor failure, observed during operating life tests, in terms of a model of surface charge separation.

ABSTRACT: While oxide passivation of planar p-n junctions has resulted in major improvements in the electrical performance of devices (by reducing surface effects), the reliability limitations of contemporary planar devices are still controlled by the properties of the oxide-silicon interface, the oxide itself, and the oxide-ambient interface, all of which are incompletely understood. This paper discusses the cause of failure in silicon planar n-p-n epitaxial transistors which occurs during life tests at 600 mw dissipation and various ambient temperatures and collector-base voltages. The I-V characteristics of the reverse-biased collector-base junction of the failures show leakage currents well above the 10 na acceptance limit. Two procedures have been employed to effect recovery: (1) Heat the transistor to 200°C without bias for several minutes (or to 300°C for several seconds), (2) Open the can and expose the transistor to normal ambient atmosphere.

The observations can be explained in terms of a model of surface charge separation under the influence of the fringing field of the reverse-biased collector-base junction. This field attracts negative surface charge toward the positively biased n-type collector and positive charge toward the p-type base. The polarity of these charges is of the proper sign for inducing an inversion layer on the surface of both the underlying base and the collector. The surface currents associated with the inversion layers so formed then dominate the reverse current characteristics of the collector-base junction.

Both of the recovery techniques permit the surface charge to redistribute itself. Heating gives the surface ions more thermal motion while the ambient exposure allows the surface adsorption of a few monolayers of water, in which the ions have higher mobility.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: The experiments described in this paper confirm the Atalla model [1] of the effect of operating voltage on oxide passivated planar junctions. The author's model of surface charge separation is identical to the Atalla model and that used to interpret the highly publicized Telstar I transistor failure and recovery (see Abstract and Review Serial Number 653). What is particularly noteworthy about these new results is that this particular failure mechanism is shown to be of considerable importance not only in the specialized environments of high humidity or radiation as discussed in the earlier works but also in the everyday working environment in which these operating life tests were performed. These new data confirm that ionic contamination in potentially damaging concentrations does exist inside encapsulated transistor cans and that some operational testing is required to detect it.

REFERENCE: [1] M. M. Atalla, A. R. Bray, and R. Linder, "Stability of thermally oxidized silicon junctions in wet atmospheres," Proc. Inst. E. E. (London), vol. 106, part B., no. 17, pp. 1130-1137, March, 1960 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A fundamental failure mechanism in thin film metal-dielectric structures observable as a generated voltage

AUTHORS: J. J. Wortman and R. M. Burger, Research Triangle Institute, Durham, North Carolina

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 173-187 (book available to qualified requesters from the Defense Documentation Center as AD434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To report a failure mechanism observed in metal-dielectric-metal structures.

ABSTRACT: Experimental observations have been made of voltages generated in metal-dielectric-metal (M-D-M) structures. The phenomenon has been called the galvano-diffusion effect and involves both a chemical reaction and a diffusion process. The effect contributes to the failure of an electronic structure, in which it is active, by changing the dimensions and thus the electronic properties of the structure.

A brief theoretical treatment is given of material diffusion across the boundaries of M-D-M structures. It is noted that the M-D-M structure is capable of functioning as a galvanic cell; the case of an $Al-Al_2O_3-Au$ structure operated in an oxygen atmosphere is discussed.

The basic measurement consists of observing the short-circuit current and the open circuit voltage generated in $Al-Al_2O_3-Au$ structures when heated to several hundred degrees centigrade. Potentials up to 1 volt and currents approaching 1 microampere have been obtained. The characteristics are similar to those expected for a high impedance galvanic cell. Typically, a specimen consists of a 2mm wide (500-1000 A thick) Al strip, vacuum-deposited on a microscope slide upon which is grown, by anodization in a 3% tartaric acid solution, an Al_2O_3 layer 150 A thick. A gold stripe is evaporated at right angles over the anodized Al film.

It is contended that galvano-diffusion as a failure mechanism might be observed:

1. In thin-film structures where a dielectric film under 500 angstroms thickness is employed to separate conductors and in which at least one of the conductors is readily oxidized, the galvano-diffusion effect may determine the useful life.

2. In hot electron or tunneling structures, special attention

must be given to the avoidance of oxidizing reactions since, even at room temperature, extraneous voltages and a short useful life result from the galvano-diffusion effect.

3. In structures wherein thicker dielectric films are used for insulation, the ionic diffusion and electrode materials must be critically examined in order to determine the allowable operating temperature. The effect of applied electric fields on galvano-diffusion may be expected to enhance the degradation process.

The types of devices most susceptible to failures of this type are: "tunneling" or hot electron devices, thin-film capacitors, and silicon surface field effect transistors.

The following measures can be taken to minimize the effect in thin-film devices:

1. Use electrodes such as gold and platinum which resist oxidization.
2. Use thick electrodes to reduce the supply of oxygen to the interface.
3. Use thick and dense dielectrics to reduce diffusion through the dielectric.
4. Operate in a nonoxidizing environment or protect from oxygen with hermetic coating.
5. Use oxygen getters in hermetic enclosures to reduce oxygen pressure. An aluminum film may serve as an efficient getter.
6. Operate at low temperatures.
7. Adjust electric field polarities to inhibit the ionic diffusion.

REVIEW: This is an interesting paper which illustrates another pitfall in the path of progress towards ultra-reliable thin-film devices. The interdiffusion of materials in thin-film components presents many reliability problems: Apparently galvano-diffusion is one more to add to the list. Perhaps the only way of obviating all of these problems would be to operate at low temperatures as suggested in item 6 above. However, this in turn creates new problems. The relative importance of this failure mechanism is not known.

The equations used in the paper are somewhat confusing in that n represents two different quantities. The authors list seven references to relevant work in the field -- none of these deals explicitly with the subject of reliability. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Introduction (to Semiconductor Reliability Volume 2)

AUTHOR: William H. von Alven, ARINC Research Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 1-8

PURPOSE: To provide a general introduction to the problems of specifying and assuring semiconductor reliability, and to indicate some of the progress which has been made in solving them.

ABSTRACT: High levels of reliability assurance for electronic parts are extremely expensive, sometimes costing more than the device itself. However, two levels of desired reliability for electronic components are beginning to emerge. One level concerns maintainable equipments for which reliability demands are less stringent and the second is associated with the nonmaintainable equipments for which the maximum reliability assurance is demanded. The device manufacturer has the basic responsibility for producing products which meet specifications, but the equipment manufacturer and maintenance agencies bear a strong responsibility for extracting the best in reliable performance from each device. High failure rates observed in some solid-state component applications are undoubtedly influenced by both poor application and and poor maintenance techniques. The maintenance problem is illustrated by the generally observed fact that field removal rates of components exceed the actual component failure rates. Considerable time and effort is usually needed to bring these rates into agreement.

Failure rates may be reduced by improved mechanical and electrical design, as well as effective use of quality control procedures. For those programs demanding extremely high reliability levels, a special screening program may be used. Typically, a good screening program is very expensive and is used only in the most critical situations. A sample screening program is given in the paper. It consists of thermal shock tests, high temperature aging, hermetic seal test, sort by type, standard military electrical, environmental, and life tests on a lot sampling basis, power aging, vibration test for operational instability, and final electrical tests. Each of the tests serves to eliminate potentially defective units since the smallest deviation from the desired limits is sufficient cause for rejection.

Five major areas where specification assurances for reliability are being improved are: (1) more information for use in matching devices and applications, (2) the inclusion of LTPD-λ sampling procedure concepts for better consumer protection, (3) better specification controls on electrical parameters required for

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

specific applications, (4) better environmental tests, and (5) "rating verification" tests. Future work points toward development of a more complete understanding of each device type and of more economical sampling procedures.

REVIEW: This article is the introduction to the collection of papers in Semiconductor Reliability Volume 2, rather than to the conference for which the papers were prepared. The author summarizes the state-of-the-art in reliability specification and assurance for semiconductor devices by noting the highlights of both this volume, of which he is the editor, and the earlier one (covered by Abstracts and Reviews Serial Numbers 336-340, 380, 1321-1337). From this background he is able to indicate directions for future development. Thus the paper serves a useful purpose as a summary of conclusions, as well as being an introduction. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Uses of semiconductor life distributions

AUTHOR: D. S. Peck, Bell Telephone Laboratories, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 10-28

PURPOSE: To discuss the importance and usefulness of studies of life distributions in the life testing operation.

ABSTRACT: Because of the increasing need for predictions of semiconductor reliability in operating systems, studies of life distributions are indicated as a part of the life testing operation. Knowledge of the distribution is required in order to (a) enable prediction of life at the life test condition and (b) provide the statistical means for evaluating acceleration factors in order to predict life at the end use condition. It is seen, however, that an erroneous distribution assumption can cause prediction errors in failure rates by large factors even in one order of magnitude of life. It is necessary, then, for life studies to be extended sufficiently to distinguish between various alternate distributions. Existing data indicate strongly the correctness of the log-normal life distribution. In this case, the nature of the failure rate curve is such as to make difficult the use of any other distribution assumption (such as the Weibull) to extrapolate life estimates from several levels of accelerated stress conditions.

It is also desirable that the life distribution be a convenient tool for interpreting the effects of manufacturing processes. The log-normal life distribution is readily plotted and easily interpretable in terms of changing processes, process controls or manufacturing or design deviations. The use of the normal distribution to fit stress-to-failure data also contributes to process evaluation.

The use of life distributions in specifications, however, may not be dependable in conjunction with the type of sampling plan in current use on semiconductors. If distributions are actually plotted and estimates made of the distribution parameters useful for reliability predictions, much can be gained in cost and time of life testing. Considerable effort and experience may be required, however, before specifications can be prepared making use of life distributions. Supplementary tests will still be required for control of manufacturing defects. They may not serve simultaneously as a measure of life and perhaps should not be called "life tests," but the establishment of efficient and economic test conditions will be facilitated by knowledge of the proper life distribution. (Author)

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This is a clear discussion of the philosophy of life testing. The necessity of determining the uniformly most accurate life distribution is strongly emphasized and a strong heuristic argument in terms of graphical evidence is put forward for the correctness of the log-normal distribution. This is a thoughtful, thorough, and well-written exposition of both the uses of life-test reliability data and the current state of the art. The emphasis on the fit at very long lives is good.

An earlier paper on a closely related topic by this author was covered by Abstract and Review Serial Number 340. No references are given in the present paper, although numbers in parentheses at various points in the text imply that it was intended to include a bibliography. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1419
Codes 822;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weibull distribution function in reliability analysis

AUTHORS: A. Procassini and A. Romano, Motorola Semiconductor Products, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 29-34

PURPOSE: To discuss the application of the Weibull distribution in semiconductor reliability analysis.

ABSTRACT: Use of the Weibull function to describe semiconductor life distributions allows for a changing failure rate. Data obtained from small-sample tests (100 to 300 units) indicate a good fit to the Weibull distribution, where the shape parameter β is less than unity (which indicates a decreasing failure rate).

Another useful function is the log-normal distribution, which may exhibit a variety of failure rates such as increasing, decreasing, and increasing-decreasing. The proper distribution must be determined on the basis of a careful examination of test data.

REVIEW: The data given indicate a good fit to the Weibull distribution; however, no attempt is made to extrapolate to times beyond the test period and reasonable doubt exists as to the adequacy of the Weibull distribution at such extreme values. The work of D. S. Peck (see Abstract and Review Serial Number 1418) indicates that the use of the Weibull distribution can yield overly pessimistic results in some situations. In general, the choice of the proper distribution is quite important, and at the same time is often difficult. The reliability analyst should regard this as a point on which he must make a carefully-considered decision on the basis of all information which he has available. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1420 -1
Codes 546;822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determination of short-term life test failure distribution

AUTHOR: Lawrence F. Jones, Westinghouse Electric Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 35-40

PURPOSE: To present the results of an investigation of the failure distributions indicated by short-term life tests on semiconductor devices.

ABSTRACT: A task group of the JEDEC JS11 committee on sampling procedures has investigated 101 sets of data provided for them on a variety of semiconductor devices to determine whether the constant failure rate hypothesis is valid for semiconductors. The data were limited to tests of 1000 hours duration and three types of tests were considered: operating life, high-temperature storage, and room-temperature storage. Due to variations in time intervals at which test measurements were made, a one-week test interval was fixed for each set of data, and numbers of failures were assumed to be proportional to time for those sets of data that included different test measure intervals.

Through the use of the chi-square goodness-of-fit test on both individual data sets and on the combined data of each of the three test types, two results were generally observed. Either the results were non-significant or they showed the assumption of of a constant failure rate for semiconductors to be invalid. A fourth test combining all three types of environment also indicated rejection of the constant failure rate hypothesis.

On the basis of these results, the JS11 committee concluded that the constant failure rate assumption does not apply to semiconductors. A decreasing failure rate seems to be more likely. The length of time for which the decreasing failure rate exists within the first 1000 hours could not be established and no conclusions are possible for times greater than 1000 hours.

A task group of the JEDEC JS11 committee is working on a sampling procedure to incorporate the use of a decreasing failure rate assumption. The specific decreasing failure rate assumed would depend on additional tests of significance.

REVIEW: This paper represents a very reasonable attempt to answer a difficult but important question through the use of available data. However, the limitation of the work to times of 1000 hours and less should be kept firmly in mind. Also it is an attempt to make sense of widely differing data, which makes the work much

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

more difficult. The use of a decreasing failure rate for semiconductor devices is now generally accepted in principle, but it is probably not used much in practice since it is harder to apply.

The paper includes a good discussion of the limitations, from a statistical standpoint, of the chi-square test as applied in this investigation. The question of statistical vs. engineering significance should also be kept firmly in mind. Even though a conclusion may be of statistical significance, the difference or relative effect may be of no engineering consequence whatsoever.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1421 -1
Codes 822;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure time distribution estimation

AUTHOR: Jimmy D. Adams, Texas Instruments, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 41-52

PURPOSE: To describe several methods of determining whether an underlying distribution is exponential, Weibull, or log-normal.

ABSTRACT: The results of recent life tests on semiconductors strongly indicate a non-constant failure rate for these devices. This rejection of the constant failure rate hypothesis leads to consideration of failure distributions other than the exponential. Two such distributions, the Weibull and the log-normal, have been extensively used and studied. Both distributions have been found to give good results when applied to transistor life-test data.

Testing for the Weibull distribution is a realistic first step in determining the best fit for a given set of life-test data. (Complete graphical procedures are given in the paper.) The exponential distribution is then checked by use of the chi-square test. Finally, a graphical check of the applicability of the log-normal distribution is made.

The results of the above distribution checks on representative transistor life-test data show little difference in accuracy between the log-normal and the Weibull distributions over the test period of 1000 hours. The exponential distribution must be rejected. Furthermore, it appears that the Weibull has the added feature that the shape parameter β is constant from sample to sample even when a process improvement resulting in a significant reliability improvement has been made.

The following conclusions are drawn from the testing and analysis of failure distributions in semiconductors:

1. The instantaneous failure rate Z(t) is not a good measure of reliability where Z(t) is not constant in time. Median life or cumulative percent failures would be a better reliability index.
2. All testing procedures for fitting distributions require a large number of failures. Therefore, accelerated life tests must be used or large samples must be run in order to get a realistic estimate of the proper distribution.
3. The Weibull distribution with non-zero location parameter is difficult to fit with testing that performs failure checks at specific intervals, since the location parameter must be subtracted from individual life lengths to give a linear plot. However, the location parameter may be safely assumed to be zero when testing such components as transistors.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: Like the three papers which precede it in Semiconductor Reliability Volume 2, this one is concerned with the determination of the proper distribution for the analysis of a set of life-test data on semiconductors. The conclusions drawn should be compared with those in the other papers. In particular, the remarks concerning the constancy of the shape parameter and the usefulness of the median life should be compared with the conclusions drawn by Peck (see Abstract and Review Serial Number 1418).

The outlines of procedures given in this paper are useful. However, the descriptions of the theoretical background are a little too sketchy. Those who are interested in the latter will do well to refer to more extensive works on these aspects, such as the three references cited in the paper.

One should be careful to distinguish between engineering and statistical significance when rejecting the exponential hypothesis.

(A minor error appears in Figure 1: 10^{-8} should read $10^{0.8}$.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1422
Codes 552;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure analysis of semiconductors

AUTHOR: John D. Atherly, General Electric Company

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 53-58

PURPOSE: To provide an approach to the determination of the failure rate of a given transistor line at a date beyond the last physical measurements, and the determination of whether a failure rate exists on a transistor line when the applied stress is too small to cause failures.

ABSTRACT: In reliability data of the attributes type, each device is recorded as good or bad. The failure rate is obtained by dividing the total number of failures per unit of time by the total number of units on test. This approach has simplicity, but when highly reliable units are operated at relatively low stress levels, extremely large samples are needed to provide good estimates of failure rate.

An alternative method, called cumulative variables analysis, enables the study of one characteristic at a time. The characteristic chosen for illustration in the paper is I_{CBO}. Percentage locations for given I_{CBO} values are found by dividing the number of units with I_{CBO} equal to or less than the given value by N + 1 where N is the total number of units on test, and multiplying the result by 100. The percentage location values are then plotted against the cumulative percent of units on logarithmic probability paper. Several values of time between zero and 10,000 hours are used, yielding several curves. The curves are extrapolated out to the 99.99 percentile region of the units. I_{CBO} is also plotted against time for various values of cumulative percent. A failure definition is then fixed in terms of I_{CBO} and a curve of time against cumulative percent failures is drawn. From this curve, failure rates at various times are obtained and plotted.

REVIEW: This is a rather brief paper which presents a graphical approach to the finding of a failure rate, given data on a critical characteristic (in this case I_{CBO}). No background for the approach is given--no references are cited. The method depends heavily on extrapolation, and therefore has a strong element of subjectivity. Such being the case, the user has no assurance as to the validity of the final results. It is also not clear just how the failure definition is determined. The paper could have been improved by the presentation of more detail, including a description in detail of an actual set of data analyzed by this method. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1423
Code 440

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Normalizing transformations for reliability data

AUTHOR: Paul S. Olmstead, Bell Telephone Laboratories, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 59-67

PURPOSE: To present an outline for the identification of an equivalent linear normal (Gaussian) distribution when it is presumed that the actual distribution is gamma, Weibull, or log-normal.

ABSTRACT: This paper presents normalizing transformations for exponential, gamma, Weibull, and log-normal random variables.

REVIEW: The transformations described in this paper may be of general interest from a mathematical point of view, but it is not clear why they are needed, in view of the tables which exist.

However, the author in a private communication, has pointed up the problem of the choice of distribution type in reliability analysis and has stated that "... my paper suggests that engineers may find it more profitable to transform their data to what might be a linear normal distribution where their intuition is less apt to lead them into trouble. For this purpose, existing tables are not in themselves of very great use. They do not answer the question 'If I were to be wrong about my choice of distribution type, what other distribution types are likely alternatives for my data?' My paper suggests that the class of likely alternatives is such that a root transformation will normalize the observed data, at least between 1% and 99%. Data outside 5% and 95% are of course subject to very wide fluctuations and cannot be considered very reliable." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1424
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor reliability data presentation

AUTHOR: C. H. Zierdt, Jr., General Electric Company

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 68-78

PURPOSE: To suggest a minimum group of formats for the presentation of reliability data, which will serve the needs of most users.

ABSTRACT: Reliability data may be presented in many forms suitable for particular uses and preferences. However, allowing for some data reduction by the user, a minimum group of data formats can be used. Information for these formats is obtained from the following three sources:

(1) Initial product measurements,
(2) Post-test parameter readings, and
(3) Process and material data.

Persons having a major interest in reliability data are:

(1) System designer,
(2) Circuit designer,
(3) Specification writer, and
(4) Supplier's product engineer.

The minimum format group should include the following:

(1) Plots of initial parameter distributions,
(2) Correlation plots between initial parameters,
(3) Graphical displays of parameter changes due to short-term stress (shock),
(4) Plots of long-term stress response,
(5) Correlation plots to show long-term stress correlation between parameters,
(6) Graphs of typical long-term and short-term failure patterns, and
(7) Failure rate versus time for particular stress levels.

The suggested forms of data presentation would fill most of the requirements of the interested personnel. Some further data reduction on their part may be necessary for specific applications.

REVIEW: The use of the format proposed would appear to reduce the time and expense involved in producing overly detailed reliability information and still present the necessary basic information on product performance that the user must have. The ideas presented are worthy of the careful consideration of those concerned with this problem, with a view to their use in or adaptation to specific situations. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1425
Codes 775;822;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductor burn-in and Weibull statistics

AUTHOR: James N. Perry, Transitron Electronics Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 80-90

PURPOSE: To show how burn-in, or aging, can help improve the reliability of delivered semiconductors, and how an understanding of the Weibull distribution can help achieve maximum screening efficiency from burn-in.

ABSTRACT: Two ways are available for increasing the reliability of delivered semiconductors, namely (1) elimination of failure mechanisms by improved production processes, and (2) identification and elimination of failures from production lots prior to shipment. The semiconductor burn-in procedure is one way of implementing method (2). Under this procedure, all production units are tested to customer specifications and then operated under stressed conditions for a set period of time. A retest of each unit is made and defective units removed before shipment to the customer.

For the Weibull distribution with shape parameter β, the burn-in procedure is effective in giving the customer greater reliability only if the failure rate is decreasing with time ($\beta < 1$). The lower the value of β, the more effective is the burn-in procedure. The feasibility of the burn-in procedure depends on whether reliability is being achieved without it, whether its use would enable the device to meet specifications, and whether its cost is justified. In the middle range of β values, economic consideration will generally prevail; however, in critical situations where utmost reliability is essential, economics will become secondary.

The selection of the most efficient burn-in procedure may be achieved by studying the effect of stress upon the Weibull β. Care should be taken to insure that the burn-in procedure does not induce failure mechanisms that do not normally appear.

REVIEW: This is a well-written discussion of the potential value of burn-in, citing appropriate methods for judging its applicability to a given device, and its potential effectiveness. However, the idea of improving the mean useful life of items by eliminating those with short lives is not new. See the paper covered by Abstract and Review Serial Number 23. That paper considered the problem from a theoretical standpoint in terms of the Weibull, gamma, exponential, extreme value, and log-normal life distributions. The present paper considers only the Weibull distribution and is application-oriented, specifically referring to semiconductors. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1426 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reducing reliability risks through failure analysis, screening, and process improvement

AUTHOR: Charles C. Packard, International Business Machines Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 91-99

PURPOSE: To demonstrate that a conscientiously applied program of failure analysis followed by appropriate corrective action is an effective method for reducing reliability risks.

ABSTRACT: High system reliability may be achieved either by improving component reliability or by the use of redundancy. A combination of these methods, weighted by considerations peculiar to the given system, may also be used effectively. Component reliability is ideally a function of physical characteristics such as material composition, bulk and interface concentration gradients, voltage and temperature stresses, mechanical stresses, etc. However, in practice, process faults tend to govern failure rates (e.g. material voids, cracks, contamination, etc.). These faults will vary from one production line to another and also with time on the same production line. Hence, meaningful reliability samples must come from production lots over a comparatively short time interval.

The objective of a failure analysis program and a testing program is to achieve sufficient reliability to meet customer needs. An effective failure analysis program may include participation by each stage of the marketing process, manufacturer, vendor, and user. Tests should be run by each group, with the user having the prerogative of rejecting any lot that shows excessive reliability risks. A feedback of all test information should be established to aid in process improvements. User failure analysis should occur on all levels, from receiving through field use. Each failure should be analyzed by reliability specialists to determine its cause and any existing trends.

Six specific examples in the form of typical problems, their analysis and solution, are given. The problems are representative of the types of failure situations encountered in the failure analysis program. Relevant observations from failure analysis data are as follows:

1. Approximately 50 percent of all assembly failures and 30 percent of all component failures are caused by interconnection or bonding difficulties.

2. Sixty percent of all diode and transistor types used suffered from loose internal metallic particle problems.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

3. Detergent techniques for gross leak detection have been ineffective.
4. Contamination is the most serious reliability problem in semiconductor devices.

REVIEW: This paper presents in a no-nonsense, production-line style of writing a convincing demonstration of the practical value of failure analysis (or the physics of failure as it is referred to elsewhere). The emphasis is not on statistically interpreting vast quantities of data from life tests, accelerated tests, etc., but on the analysis of specific case histories of failure. The paper preceding this one in the book (see Abstract and Review Serial Number 1425) mentions two ways which are available for increasing semiconductor reliability. This paper illustrates dramatically the implementation of the first of those ways--that of production process improvement. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1427
Codes 813;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A practical defect analysis program

AUTHORS: Dewitt W. Davis and Phil F. Southern, Texas Instruments, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 106-110

PURPOSE: To describe the Defect Analysis Program established in the Transistor Products Division at Texas Instruments, Inc.

ABSTRACT: A defect analysis program demands competent and enthusiastic engineers and scientists as well as a well-equipped test laboratory. However, the results of such a program should more than justify its cost. Defect analysis of all failures, including inplant failures and failures returned by customers, provides a valuable source of information regarding possible procurement and production process changes.

A satisfactory defect analysis program demands full cooperation by the customer. A unit that has failed in the field should be returned with all possible information on application conditions and the circumstances leading to the failure. Examination of the failed unit by means of electrical measurements, hermetic seal tests, environmental tests, chemical analysis, microsectioning, etc. in light of the use conditions to which it was subjected can then yield an accurate determination of the cause of failure and suggest pertinent process or design corrections.

The Defect Analysis Program in the Transistor Products Division at Texas Instruments, Inc. is described. The objectives of the program and the steps in the analysis are outlined. Reliability problems which the program has solved or reduced are indicated.

REVIEW: This paper serves to give a good indication of the philosophy and thinking required to establish and operate a defect analysis (physics of failure) program. The specific operating modes of the program evolved as individuals implemented the goals as they saw fit; there was no well-established pattern to follow. The success of a program so organized depends heavily on the ability, ingenuity, and initiative of the personnel involved. This program has apparently been quite successful. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1428
Codes 813;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure analysis program at the component level

AUTHOR: J. R. Bevington, Delco Radio Division, General Motors Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 111-117

PURPOSE: To describe a failure analysis program at the component level.

ABSTRACT: Delco Radio achieved a significant improvement in the reliability of their semiconductor devices by instituting a failure analysis program at the component level. The concept of failure or "defect" analysis is relatively new and has grown out of the need to close the feedback loop on military systems failures.

Failure analysts should be specialists with a wide range of analytical backgrounds. With such personnel, elusive information overlooked in more cursory examinations may be pinpointed and used to eliminate costly failures. Major features of the Delco Radio Failure Analysis Program are:

1. A formal test program to furnish an analytical method of investigation.
2. Careful and detailed documentation of all observed information.
3. Intragroup autopsy meetings for the purposes of discussion and advance planning.
4. Detailed reporting of results and conclusions.
5. Periodic intergroup meetings with manufacturing, test, and processes personnel.
6. Maintenance of up-to-date files of all work for reference purposes.

All defective units are subjected to a standard test program (given in detail in the paper). Three levels of analysis are used, the extensiveness of the analysis being determined by the boundary conditions of economics, nature of failure, and relative importance of the device. A typical case history is reviewed.

REVIEW: The goals and implementation of this failure analysis program are similar to those described in the papers covered by Abstracts and Reviews Serial Numbers 1426 and 1427. This particular description is somewhat more detailed and reflects perhaps a more formal and organized program. Nevertheless, the ingenuity of the analysts performing the "autopsy" still determines the program's value. There is specific emphasis placed on documentation throughout the failure analysis. The paper also lists specific procedures for accomplishing certain basic operations often casually taken for granted, such as the removal of a welded cap from a transistor header and the subsequent removal of the semiconductor chip. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1429 -1
Codes 775;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction, screening, and specifications

AUTHORS: Julian Hilman, Fairchild Semiconductor Corporation (now with General Instrument Corporation) and Frank Durand, Fairchild Semiconductor Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 118-123

PURPOSE: To describe screening techniques for silicon transistors, discuss their effectiveness, and to comment on the specification of screening procedures.

ABSTRACT: Fairchild Semiconductor Corporation has applied screening techniques to test samples of 6800 NPN silicon mesa transistors (Type 2N697) and 1700 NPN silicon planar transistors (Type 2N1613), operated for approximately 5000 hours under varied stress conditions. The screening technique is based on the parameter I_{CBO} at 30 volts reverse collector bias. Graphical display of the resulting data for the mesa transistors shows a remarkable population stability as well as a small proportion of mavericks having parameter values far in excess of the population average. Results also show that burn-in or aging is a very effective means of eliminating potential failures for the silicon mesa type transistor. At a small sacrifice of stable units, 85% of the unstable units were eliminated. The aging process was found to be less effective when applied to the silicon planar transistor due to its smaller leakage current and greater population stability.

Whether the cost (to the customer) of the screening process is justified depends on the degree of reliability improvement obtained and whether or not the added reliability is really required. A screening program should be used only on devices which will benefit from it. Ways of implementing this are as follows:

1. Specify a screening technique, but permit it to be waived if the process for a given vendor is qualified on a periodic basis, demonstrating the inefficacy of the screen.
2. Specify a screening technique, but allow it to be waived if the first lot 100% results show it to be unnecessary.
3. Ignore the screening process by considering it a part of the manufacturing process. Instead require a very high reliability by allowing very few failures in a large-sample life test.

No single screening technique can be applied to all semiconductor devices. All screening specifications should have a built in waiver.

REVIEW: The authors feel that "exotic theories..based on small amounts

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

of test data and large amounts of extrapolation, assumption, and wishful thinking" are no substitute for actual experience. They seem to have the data to back up this general statement, insofar as silicon transistors are concerned. The performance of the mesa units looks acceptable enough but the planar transistors do even better in the particular test configuration illustrated. The authors argue that the screening test that significantly improved the mesa units is inappropriate for the planar units and illustrate the point clearly. They could also point out the major reduction in failure rate brought about by the production process improvement realized in changing from mesa to planar structures. It would be interesting to know what screening test has been developed for the planar transistors. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1430
Codes 341;720;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Lot control system as a means for reducing failure rates

AUTHOR: Sidney Wiesner, Rheem Semiconductor Operation, Raytheon Company (now Raytheon Company, Semiconductor Division, Mountain View Operation, 350 Ellis Street, Mountain View, California)

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 124-129

PURPOSE: To describe a system of lot control in transistor manufacture which places emphasis on building reliability into the product, rather than testing for it.

ABSTRACT: Lot control techniques may be used to reduce failure rates, improve electrical yields, and reduce costs, as illustrated by a double-diffused silicon mesa transistor (Type 2N697). The lot control process consists of taking groups of wafers from the same ingot and keeping a careful record of their characteristics throughout the manufacturing process. Electrical tests are made at desirable points in the manufacturing process, and charts of the average and range of the electrical yield of each lot are drawn. This process allows the detection and rejection of early failures, saving the cost of the rest of the manufacturing process. Finally, if a completed lot is found to be defective, then the complete record of its history will aid the efforts of the failure analysis group in determining the cause of the failure and prescribing corrective measures.

By using the lot control method, small samples of the device may be tested to yield sufficient criteria for the entire production. This is due to the following two facts: (1) the entire lot is homogeneous by the nature of its manufacture and the fact that all wafers came from the same ingot, and (2) the reliability assurance group learns to evaluate not a single diffusion lot by itself, but reliability trends for a series of diffusion lots, thus providing the necessary assurance for each individual lot.

REVIEW: A method of process control has been outlined that facilitates the pinpointing of trouble spots in the production line. The procedures described rely heavily on routing sheets complete with operator initials and dates. The added bookkeeping burden seems a small price to pay for the historical information thereby acquired. It is difficult to visualize a production line operating effectively without such information. The forms and procedures described here seem appropriate for doing the task assigned to them. It is worth emphasizing that the underlying philosophy of this approach is that reliability is a characteristic to be built into the product, not something which can be tested into it.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1431
Codes 840;850

782;824;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Concepts and research needs of reliability in military systems

AUTHOR: E. J. Nucci, Office of the Director of Defense Research and Engineering, Washington, D. C.

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 1-4

This paper is similar in major content to the one covered by Abstract and Review Serial Number 1231.

TITLE: Electronic part failure rates in space environments

AUTHOR: John A. Connor, ASTRO Reliability Corporation, Sherman Oaks, California

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 5-10

This paper is identical to the one covered by Abstract and Review Serial Number 1216. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1432
Codes 872;882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dependability of a complex system having two types of components

AUTHOR: R. C. Garg, Naval Research Group, Defense Science Laboratory, Metcalfe House, Delhi, India

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 11-16

PURPOSE: To examine the behavior of a complex system having two classes of components such that a failure in the first class causes a reduction in efficiency whereas a failure in the second class causes complete system breakdown.

ABSTRACT: In this paper, the behavior of a complex system having two types of components is examined with regard to dependability. The Laplace transforms of various probabilities for the general case have been obtained and from this, for some particular cases, the probabilities that the system is operating under usual efficiency or reduced efficiency, or is in the failed state are deduced. In the end, the behavior of the system under steady state has been examined. The supplementary variable technique has been employed to solve the problem. References to earlier and related work are cited. (Author in part)

REVIEW: This is an extension of the work in the paper covered by Abstract and Review Serial Number 417. It is a competent piece of mathematics, but no attempt is made to discuss or illustrate its applicability. Accordingly it will be of more interest to the theorist than to the design engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dependability of a complex system with general waiting time distributions

AUTHOR: R. C. Garg, Naval Research Group, Defense Science Laboratory, Metcalfe House, Delhi, India

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 17-21

PURPOSE: To examine the behavior of a complex system having n components with exponential failure and repair times, with the assumption of general waiting time distributions.

ABSTRACT: This paper considers the possibility of the inclusion of general waiting time distributions for a failed system while examining its behavior with regard to dependability. The probabilities that the system is operable, waiting for repair, or under repair are obtained. Some particular cases are also discussed in detail. The behavior of the complex system under steady state has also been examined. It may be noted that in the particular case when the simple system is put under repair instantaneously the results correspond to those obtained by Hosford [1].

REFERENCE: [1] J. E. Hosford, "Measures of dependability," Operations Res. vol. 8, January-February; 1960

REVIEW: Like the paper covered by Abstract and Review Serial Number 1432, this paper is a competent piece of mathematics, but no attempt is made to discuss or illustrate its applicability. Accordingly it will be of more interest to the theorist than to the design engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1434 -1
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quadded NOR logic

AUTHOR: Paul A. Jensen, Electronics Division, Westinghouse Electric Corporation, Baltimore, Maryland

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 22-3.

PURPOSE: To describe and analyze quadded logic using the NOR gate as an example basic block.

ABSTRACT: Quadded logic, a technique for the introduction of redundancy to digital systems, allows a number of component failures to occur in the system without disturbing its capacity to perform the function for which it was designed. This paper describes quadded logic using the NOR gate as the basic building block. A reliability prediction technique is shown with which the performance of this redundancy scheme can be evaluated. The gains in reliability possible through the use of quadding depend on the reliability of the nonredundant gates that make up the redundant stage. Where these gates are already very reliable, the probability of failure of the NOR function can be reduced by several orders of magnitude.

The quadded network has the ability to withstand any single component failure and probably a good many more. The best logical elements to use in the network are ones designed so that branch failures are unlikely and gates have low numbers of input variables. Quadding is most effective when the components of the system have high reliabilities.

A reliability analysis similar to that described by this paper is applicable to the other forms of quadded logic, NAND or AND/OR, as long as component gates conform to the model illustrated. Then given the logical requirements of a network to be constructed, the type of gates to be used, and the several probabilities associated with each gate, this paper provides the means for predicting the reliability of the quadded network. This information is necessary for justifying the use of quadding over the less expensive nonredundant construction and for comparing the quadded network with other methods for applying redundancy to digital gates. (Author)

REVIEW: This analysis is carried out on a non-elementary level and the results are left on that level. This means that the ordinary design engineer will have some difficulty in applying the results although it may be within his capabilities to do so. The results were not checked in their entirety, but the work appears to be of high caliber. (Some of the notation in the description of the

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

half adder is, unfortunately, very poorly chosen, but fortunately it is not essential to the main discussion.) It would be helpful if the work were extended to specific situations.

Several restrictions in the paper are worth keeping in mind. These are the following.

1. The failure probability of a component is in no way affected by the condition of other components. (There should be added to this the qualification: "under a specific set of operating conditions." In the event that there is more than one set of operating conditions, the failure of a component changes the a priori probabilities of each set of operating conditions and thus effectively changes the unconditional probability of failure of a component.)
2. The outputs of a stage go to only one other stage. (This restriction is violated in part of the derivation, i.e. stage D. The exact ways in which this restriction is necessary are not obvious.)
3. All stages have the same number of inputs. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1435
Code 822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Shapes, moments and estimators of the Weibull distribution

AUTHOR: Eugene H. Lehman, Jr., Houston Fearless Corporation, Los Angeles, California, and University of Southern California, Los Angeles

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 32-38

PURPOSE: To describe in detail some properties of the Weibull distribution.

ABSTRACT: This paper describes the properties of the Weibull distribution with density function given by

$$f(t;\,\alpha,\,\beta,\,\gamma) = \frac{\beta}{\alpha^{\beta}}\,(t-\gamma)^{\beta-1}\exp\left[-\left(\frac{t-\gamma}{\alpha}\right)^{\beta}\right],\ t \geq \gamma,$$
$$= 0,\, t < \gamma,$$

where $\alpha > 0$ is a scale parameter in "t" units, $\beta > 0$ is a shape parameter (dimensionless), and γ (any real value) is a location parameter in "t" units.

An analysis of the properties of the Weibull density function is given, indicating its suitability when MTBF is a function of time. The shape is shown to be controlled by the parameter β. When β is less than one, MTBF decreases with time; if β is one, the distribution is exponential with constant MTBF; as β approaches infinity, MTBF increases with time. The mean increases with β while the variance decreases. Skewness is to the right with small β, becomes zero with increasing β, then slightly to the left, and finally again zero as β increases indefinitely. Kurtosis is very large when β is small, decreases to somewhat less than normal, then increases to infinity with β. Regardless of the shape parameter, 36.8 per cent of the distribution fails after time $\alpha + \gamma$. Maximum likelihood equations for the three parameters have been derived, but cannot be solved explicitly. Electronic computer methods could yield iterative solutions. The properties of the maximum likelihood estimators, such as bias, consistency, efficiency, and sufficiency could be studied, perhaps by Monte Carlo methods.

REVIEW: This is a good and comprehensive paper (the mathematics was not checked in detail). The properties described are interesting and should be of some value--more so to theoreticians than to practicing design engineers. Unfortunately the notation in the final maximum likelihood equations is not adequately explained, so that those equations are of little value to the reader. Other papers dealing with the Weibull distribution and various aspects of its role in reliability analysis have been covered by Abstracts and Reviews Serial Numbers 320, 437, 499, 749, 751, 801, 848, 1015, and 1171. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1436
Codes 821;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Probability maps

AUTHOR: Richard B. Hurley, IBM General Products Division Development Laboratory, San Jose, California

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 39-44

PURPOSE: To show a new kind of probability map.

ABSTRACT: A map method, similar to Boolean-algebra-type truth maps, is presented for solving probability combinatorial problems. This map technique is shown to be of universal application and simplicity, being equally useful for both series-parallel and nonseries-parallel types of probability combinations. Moreover, it is extendable, in two dimensions, to any finite number of variables.

A probability combination problem can be broken down into its independent events. A block diagram can then be drawn, illustrating every possible combination of independent events that together can bring about the over-all complex event. A probability map (truth-map format) can be drawn in which every path through the diagram represents an intersection of the corresponding variables. These intersections are filled with ones. All filled cells are then covered once, and only once, to obtain the over-all probability function as a sum of mutually exclusive terms, each of which is a product of independent probabilities.

This map method is "universal" in the sense that it is a uniform technique which can be applied equally well to all probability combinations, regardless of whether or not they fit the simpler series-parallel cases and regardless of the (finite) number of variables (independent events). (Author)

REVIEW: This is an interesting and potentially useful tool for those who do system analysis. The claim that only two dimensions are needed is misleading since several "separate" pictures may be needed in lieu of more than two dimensions. It should be emphasized that the analysis is for a logic diagram not the circuit diagram. The question of independence is also important. It is implied that the units are independent under a specific set of operating conditions. If there is more than one possible set of conditions, with known probabilities for each, the units may still act as if they are dependent.

Unfortunately the author did not give a method for constructing the maps in general. It may turn out that getting the map in some situations is the hard part. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1437
Codes 550;821;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The use of Boolean algebra and a truth table in the formulation of a mathematical model of success

AUTHOR: A. F. Premo, Jr., North American Aviation Corporation, Los Angeles, California

SOURCE: IEEE Transactions on Reliability, vol. R-12, September, 1963, pp. 45-49

PURPOSE: To show how to use a short-cut "truth table."

ABSTRACT: This paper presents a simple, and yet rigorous approach in developing the mathematical model of success in the reliability analysis of complex systems.

Shown are detailed methods of computation of reliability where dependent or mutually exclusive failure modes are involved. It may also be applied in the statistical analysis of interrelated functions.

The methods of Boolean logic are combined with the theory of probability to determine a computational routine for the development of the reliability model. (Author)

REVIEW: The procedure seems quite adequate and straightforward, although somewhat complicated--however, no more so than any other method for accomplishing this purpose. The same results could be obtained by an ordinary expansion of the probability expression; for example, using the notation defined in the paper we might write

$$P[(A+B)(B'A'+C')(C)]=P(C)P(A+B|C)P(B'A'+C'|A+B,C)$$
$$=P(C)[P(A)+P(B)-P(A)P(B)][P(B'A'|A+B)+P(C'|C)-P(B'A'|A+B)P(C'|C)]$$
$$= \ldots$$

Without too much effort these can be reduced to expressions involving $P(A)$, $P(A')$, $P(B)$, ..., $P(C')$. Use is made of such physical conditions as $P(B'|\bar{B}) = 1$.

In general the choice of best method will be based on familiarity rather than on an inherent superiority of one method over the other. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1438
Codes 715;770;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation: the newest environment

AUTHOR: Arnold Pollack, Aerotest Laboratories, Inc.

SOURCE: Environmental Quarterly, vol. 9, September, 1963, pp. 28-30

PURPOSE: To acquaint the test engineer with the radiation environment which space systems will encounter.

ABSTRACT: Radiation--electrons, neutrons, gamma rays and other types--is the newest environment with which the test engineer must cope. At a minimum, he must be able to specify the types of radiation, dosage and exposure times for a condition with which he may not, as yet, be too familiar.

Both material and component tests should precede actual assembly of equipment to assure reasonable radiation resistance of assembled and integrated equipment. Additionally, final testing of the entire package is usually advisable. Very often components that do not withstand direct exposure can be used if the equipment itself provides inherent shielding.

For systems designed to operate in space, final testing requires exposure to accelerated, intense radiation involving particles, rays and vacuum. It is carried out in a particle accelerator, solar (UV) simulator, or gamma ray and X-ray chamber. For nuclear reactor systems, final testing is a long-term program performed in an in-pile radiation facility--a hole or recess of a working reactor. The reactor used in the test must provide the same radiations and intensities as will be "seen" by the system in future service.

Two classes of tests: material and operational are described. The siumlation of long exposure periods with accelerated, short-time, high-flux irradiations is discussed. The effects of the various types of radiation expected to be encountered are briefly indicated, together with their implications relative to testing and test equipment. (Author in part)

REVIEW: This is a brief paper, but it is cogently written and should serve its indicated purpose. The effects of the radiation environment is an area in which knowledge is being accumulated quite rapidly and a considerable body of relevant literature is developing. No references are cited in this paper, but listings of Abstracts and Reviews of papers on the effects of radiation and other environments are given in Reviews Serial Numbers 821 and 1280. Other papers bearing on this subject have been covered by Abstracts and Reviews Serial Numbers 1343, 1346, 1354, 1356, and 1393. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1439
Codes 773;783;841

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The transit environment

AUTHOR: William J. Simpson, General Electric Company

SOURCE: Environmental Quarterly, vol. 9, December, 1963, pp. 28-30

PURPOSE: To present typical cases indicating the contribution made by advanced instrumentation and environmental testing techniques to the improvement of the reliability of transportation equipment.

ABSTRACT: Environmental conditions for transportation equipment are varied and complex. They include thermal, mechanical, electrical and magnetic conditions, as well as moisture, gases, dirt, abrasives, pressure and other factors. In the past, environmental data were usually collected only when a problem was encountered after equipment was already in service. Measurement devices, if available at all, were relatively bulky and, in some cases, were not adaptable to field service. The vagaries of environment were licked by overdesign and by the elimination or modification of systems or units without full recognition of the basic causes of failure.

It would be a gross overstatement to say that, today, all problems connected with instrumentation, measurement, and usage of data have been solved. But important advances have been made, and the reliability of transportation equipment has been greatly improved.

As typical illustrations of current practice in procuring and using data, the recording and monitoring instruments used in tests on railroad multiple-unit and urban transit cars are described. Instrumentation included multi-channel magnetic tape recorders, calibration meters, monitoring oscilloscopes, Visicorders, automatic cameras, current- and voltage-measuring reactors, accelerometers, thermocouples, strain gages, and temperature-sensitive papers. (Author in part)

REVIEW: While the details described in this paper relate specifically to the environmental testing of railroad cars, the broader aspects of the problem may well have wider implications. The steps taken to obtain environmental data in the situation described may suggest counterparts in other situations in which test engineers face problems.

The author, in a private communication, has indicated that the complete paper upon which the Environmental Quarterly based its article originally appeared as IEEE paper CPA 63-5002, titled "Environmental Testing for Transit Applications" by W. J. Simpson, Member, IEEE. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1440
Codes 813;851

812

813;817

813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: AGREE-able experience

AUTHOR: Paul J. Goldin, RCA Aerospace Communications and Controls Division

SOURCE: Environmental Quarterly, vol. 9, June, 1963, pp. 24-27, 36

This paper is essentially the same as the one covered by Abstract and Review Serial Number 1040.

TITLE: A curriculum for reliability engineering

AUTHOR: Harold C. Jones, Electrical Engineering Department, University of Maryland

SOURCE: Environmental Quarterly, vol. 9, June, 1963, pp. 34-36

This paper is essentially the same as the one covered by Abstract and Review Serial Number 870.

TITLE: PORP...parts oriented reliability...program and problems

AUTHOR: C. S. Bartholomew, The Boeing Company

SOURCE: Environmental Quarterly, vol. 9, September, 1963, pp. 22-24, 40

This paper is essentially the same as the one covered by Abstract and Review Serial Number 872.

TITLE: Reliability in small companies

AUTHOR: Melbourne D. Johnson, Santa Barbara Research Center

SOURCE: Environmental Quarterly, vol. 9, December, 1963, pp. 32, 33, 42

This paper is essentially the same as the one covered by Abstract and Review Serial Number 873. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1441
Code 870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability prediction and measurement

AUTHORS: B. L. Retterer and R. L. McLaughlin, RCA Service Company, Camden, New Jersey

SOURCE: Industrial Quality Control, vol. 20, December, 1963, pp. 16-20

PURPOSE: To describe the results of a research program leading to the development of a maintainability prediction and measurement technique.

ABSTRACT: This paper describes the results of a maintainability techniques study sponsored by the Rome Air Development Center. The objectives of the quantitative treatment of maintainability during design, manufacture, and operation of equipment are outlined. Time-related, cost-related, and capability-related maintenance indices are described. Maintenance time was considered to be a function of three parameters: design, personnel, and support. Multiple linear regression analysis was used to develop a relationship involving these parameters. Scoring criteria were developed for the maintainability factors appearing within the design, personnel, and support parameters. The approaches used in obtaining data are outlined. The use of the prediction technique to evaluate the maintainability of an equipment is described. The technique has been tried and has proven successful on two equipments.

REVIEW: This paper is apparently a later report on the study described in the paper covered by Abstract and Review Serial Number 481. Like the earlier paper, it summarizes the major findings of the study. Other papers on somewhat different aspects of the same program were covered by Abstracts and Reviews Serial Numbers 1039 and 1179. None of these earlier papers are cited in the present work. However, nine references are given, and some of these should be helpful to the reader who desires more detail than is provided in this paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1442
Codes 412;550;553;
821;822

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: MTBF confidence limits

AUTHOR: Thomas A. Simonds, Bendix Systems Division, Ann Arbor, Michigan

SOURCE: Industrial Quality Control, vol. 20, December, 1963, pp. 21-27

PURPOSE: To show the basic mathematical formulas which have been developed for MTBF confidence limits, to present MTBF multiplication factor tables containing these limits, and to illustrate their use.

ABSTRACT: Confidence limits are well developed in the field of quality control as they apply to the mean and standard deviation for the normal distribution. In the reliability field, however, the exponential distribution, with its accompanying distributional parameter, mean time between failures (MTBF), is of greater usefulness and has been treated only very sketchily with respect to the confidence limits associated with the MTBF. This article shows the mathematical formulas which have been developed for MTBF confidence limits, presents MTBF multiplication factor tables containing the developed confidence limits, and explains the use of these tables with appropriate examples. The confidence limits considered are for the case of the fixed-time truncated life test in which one or more equipments are put on test until a certain amount of total test time has elapsed. In this type of test, failed equipments are replaced and total test time is the sum of the times that the individual equipments have operated. Once this designated amount of total test time has been reached, the test is stopped and the total number of test failures occurring up to then is recorded. (Author in part)

REVIEW: The author has accomplished his stated purpose very well; the material is clearly and competently presented. The tables are quite extensive and should prove very useful in obtaining confidence interval estimates of the parameter of the exponential distribution on the basis of fixed-time truncated life tests. Care should be taken to be sure that this is the type of test which was run, and that it is reasonable to assume an underlying exponential distribution. One point not brought out by the author is the fact that the confidence levels obtained by this method are <u>minimum</u> levels. A typical confidence statement would read: "The confidence is 95% <u>or</u> <u>more</u> that ..." Specifically in Example 3 one should say that the confidence level is 68.7% <u>or</u> <u>more</u>. For this example it can be shown that an upper bound on the confidence level is 80.9%. In situations in which fewer failures are observed, the difference between the minimum level and the upper bound can be greater than in this case. This point can be worth keeping in mind in the event that something other than the most conservative result is desired. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1443
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Have you heard?

AUTHOR: F. E. Wenger, Hq AFSC, Andrews AFB, Washington, D. C.

SOURCE: Industrial Quality Control, vol. 20, January, 1964, pp. 21-22

PURPOSE: To emphasize the fact that reliability pays--it does not cost.

ABSTRACT: In the state of technology which prevails today, we should not be asking how much a reliability program should cost, but rather how much unreliability we can afford, on the basis of both economic and national survival considerations. Reliability can be expressed and demonstrated in various ways, and the engineer must select the one that gives him the desired reliability information at the most reasonable cost.

Some of today's systems, which demand unprecedented performance, are very complex and costly and are often produced in small quantities. Seldom is there an opportunity to conduct a product improvement program. Therefore the equipment must be built right the first time.

An example is presented showing the savings effected through the application of an aggressive reliability program to a complex system. The economics of reliability are presented in terms of savings in maintenance costs, increase in availability, and reduction of downtime. (Author in part)

REVIEW: The message in this paper would appear to be directed at management at a policy-making level. The essential point which is made is that while good engineering practice costs more than marginal engineering, it pays off when the overall economics of the situation are considered. If the message is to be effective, it must be clearly kept in mind by those who make policy in procurement as well as in design, development, and production.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1444
Code 814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Value vs. reliability

AUTHORS: (Task Group M of the ASQC Reliability Engineering Technical Committee)

SOURCE: Industrial Quality Control, vol. 20, February, 1964, pp. 6-10

PURPOSE: To report on a study made to establish whether value engineering is a part of reliability or is a contiguous but separate function.

ABSTRACT: The two biggest problems confronting the military and industry today are: (1) the high cost of equipment and (2) the achievement of suitable reliability. These problems, posed by increased complexity, higher initial costs, and higher overall costs are attacked by value engineering through an objective appraisal of a system or product from the standpoints of specification, design, and manufacture in order to achieve desired performance, reliability, and maintainability at the lowest overall cost. This report covers a comparison and analysis of value and reliability directed toward a solution of the problem of arresting the trend toward higher costs, greater complexity, and attendant poor reliability.

Some of the more common reasons for the unnecessarily high cost of equipment are cited. It is indicated that value engineering can cope with these in such a way as to develop an equipment to perform a stated design function at the least cost commensurate with performance and reliability, and at the same time provide assurance that further improvement is unlikely to be achieved within the state-of-the-art. The problem of deciding how value engineering should fit into the present concepts of management organization is discussed. Opinions of several members of Task Group M are quoted. It is indicated that while no one in the group felt that value and reliability were unrelated, there was definite disagreement as to how close the relationship should be, and how the two should fit together organizationally. A recommendation is made to the effect that an office or group be set up to maintain close and continuous liaison between ASQC and the Society of American Value Engineers.

REVIEW: This report will be of interest to management personnel concerned with the organizational problem considered. It provides a reasonable summary of the thinking of the particular task group. However, many readers may well conclude "that the Product Assurance profession is rent by disagreement on its own scope and objectives," as pointed out by Leslie W. Ball in a Letter to the Editor in <u>Industrial Quality Control</u>, vol. 20, May, 1964, p. 6. As Dr. Ball suggests, it would be well to keep the subject alive with a view to obtaining a greater degree of agreement. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1445
Codes 830;836

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design qualification

AUTHOR: Thomas A. Simonds, Electro-Mechanical Research, Inc., Sarasota, Florida

SOURCE: Industrial Quality Control, vol. 20, February, 1964, pp. 11-13, 15

PURPOSE: To indicate that much qualification testing today is incorrectly applied and/or incorrectly executed.

ABSTRACT: Qualification tests are those tests performed to demonstrate that a manufactured article either does, or does not perform within specified tolerances over the range of its operational and environmental criteria. The intent of qualification testing is to evaluate the design of the article as well as the effectiveness of the manufacturing process.

Other forms of testing include developmental tests, acceptance tests, environmental tests, preproduction tests, first-article evaluation tests, and design approval tests. The nature and intent of each of these forms is stated briefly. It is indicated that they are commonly taken to be synonymous with qualification testing, leading to confusion. One result of this is the misunderstanding that design capability is the important factor in qualification testing and that a sample size of one is sufficient. Another result is that often hand-crafted samples are tested, instead of items randomly selected from production lots. It is indicated that improvement in this field can be gained most quickly by a revision of sample size and sample selection for testing. It is suggested that a joint program be initiated between the aircraft and missile industry on the one hand, and those responsible for writing government specifications on the other, for the purpose of accomplishing this revision. (Author in part)

REVIEW: The author has made his points clearly and forcefully, and the paper is worthy of the attention of those concerned with either the specification or conduct of qualification tests. The misconceptions described in the paper may not be as widespread as the author implies. However, suitable action to clear them up wherever they do exist should be well worth the effort. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1446
Codes 222;823;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Hazard rate sampling plans for the Weibull distribution

AUTHORS: H. P. Goode and J. H. K. Kao, Cornell University, Ithaca, New York

SOURCE: Industrial Quality Control, vol. 20, February, 1964, pp. 30-39

PURPOSE: To present a procedure, together with necessary tables of products, for applying the MIL-STD-105C plans to acceptance sampling inspection when the quality of items in the lot is evaluated in terms of the hazard rate at some specified time.

ABSTRACT: A procedure is presented for applying the MIL-STD-105C plans to acceptance sampling inspection when the quality of items in the lot is evaluated in terms of the hazard rate as a function of time. Inspection of sample items is by attributes with life testing curtailed at some pre-assigned time. The Weibull distribution is assumed as the underlying life length model. The location and shape parameters of the Weibull distribution must be known or estimated from theory or previous experience. The value of the scale parameter need not be known explicitly, as the hazard rate contains information on its magnitude.

The selection of a suitable plan, the determination of its operating characteristic in terms of hazard rate for a specific plan, and the determination of an appropriate life testing time are all made through the use of 10 tables covering a range of Weibull shape parameters from 1/3 to 4. The probability of acceptance for a lot depends only on the probability of an item failing before the end of the test period, t. The actual life at which an item fails is not needed since inspection is on an attribute basis. The operating characteristic for any sampling plan specified by the acceptance number and sample size depends only on t and Z(t), the hazard rate. With t and Z(t) specified, a sampling plan can be selected. Each table provides tZ(t) for each combination of sample size code letter and the rejection numbers used for each Acceptable Quality Level of the 105C plans. From the procedure, plans may be evaluated in terms of either the producer's risk or the consumer's risk. By simple modification, double or multiple sampling can be used.

REVIEW: This is a modified version of the paper covered by Abstract and Review Serial Number 756. The modification centers about the use of sample sizes and acceptance numbers specified for MIL-STD-105C plans, whereas those in the earlier paper corresponded to MIL-STD-105B. This paper is the latest in a series in this topic area by these authors. It contains a brief literature review, citing the other papers. See also Abstracts and Reviews Serial Numbers 46, 202, 208, 995, and 1016. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1447
Codes 010;800;801;
810;840;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and quality in communications

AUTHOR: E. G. D. Paterson, Bell Telephone Laboratories, Inc.

SOURCE: Industrial Quality Control, vol. 20, March, 1964, pp. 15-23, 31-38

PURPOSE: To discuss some aspects of reliability and their relationships with quality control as evidenced in the communication industry.

ABSTRACT: This article is a critique of reliability prediction, together with a consideration of some of the basic requirements for the attainment of reliability, presented against a background of experience in the communication industry. The semantic difficulties involved with the terms "quality control," "quality assurance," and "reliability" are discussed. The practice of quality assurance and that of reliability in the Bell System and the Western Electric Company are described. Some of the limitations, difficulties, and uncertainties associated with reliability prediction are discussed.

Methods commonly used for obtaining data for reliability prediction are described as including environmental testing, accelerated life testing, and inductive simulation. The characteristics and limitations of these approaches are given. The problem of obtaining a confidence limit on a system reliability prediction is discussed. No prediction formula can be expected to cope with the unguarded and the unknown, including the human element, and the general characteristics described as workmanship.

It would help if more of the available literature explained how to solve the problem--how to define, evaluate, and control those qualities which provide the actual source of reliability. In this way it should be possible to attain it with relatively little use of quantitative prediction. Experience in the communications field shows that it is important to design, manufacture, and use components and systems of a quality compatible with the needs of the situation to achieve reliable operation.

REVIEW: This paper presents a generally pessimistic and critical attitude toward much of the current practice in reliability prediction. To the extent that it may prompt some reasonable introspection on the part of reliability engineers, it has value. But it seems to have little to offer in the way of specific, constructive suggestions for improvement. The main theme is "it has been done in the communications industry." No one will deny this, but it must be remembered that the communications industry has had many decades in which to achieve maturity. Such is hardly the case in the missiles and space fields in general. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Government and the inspector

AUTHOR: R. W. Smiley, CDR USN, Polaris Missile Facility--Pacific, Bremerton, Washington

SOURCE: Industrial Quality Control, vol. 20, April, 1964, pp. 4-7

PURPOSE: To emphasize the importance of the inspection function in attaining reliability in modern missile and space programs.

ABSTRACT: The experience in Polaris, as well as other missile and space programs, indicates quite clearly that the key to attaining the high levels of reliability is not so much the design problem as it is the need for more "painstaking attention to details in a system of checks and balances." The inspector is a very important element in such an approach. He must do three things himself: first put major emphasis on inspection of hardware; second, take initiative to stay abreast of advances in inspection and product technology; third, display old fashioned intestinal fortitude to insist on thorough inspection of all hardware despite extreme pressures from all sides.

But as managers, we have responsibilities to support the inspector and help him provide the more rigorous inspection we need. These responsibilities include: first, improving top management's attitude toward the need for more and tighter inspection, giving inspection and inspectors a fair deal in terms of such things as time, space, money, head count and pay scales; second, providing complete engineering support in the form of classifications of defects, modern test and inspection equipment, detailed written inspection instructions, engineered space and calibration systems; third, relieving the inspector of unnecessary paper work and of MRB (material review board) functions, and relieving the chief inspector of the responsibility for providing the support for the inspector.

When these changes are made--and none of them are state-of-the-art advances in inspection technology--we will have inspectors capable of providing the kind of inspection needed in today's high reliability missile and space programs. (Author)

REVIEW: This is a well-written paper which deserves the careful attention of both inspectors and management on missile and space programs. The author has made his points clearly and forcefully. While adequate inspection is not all that is needed for the achievement of reliability in equipment, it is worthwhile to have attention drawn to its importance as an element in overall production cycle. A big problem lies in getting all concerned to give continuing literal implementation to the precept of "painstaking attention to details...." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1449
Codes 320;812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Film of the month program

AUTHOR: Jay Scovronek, ACF Electronics Division, ACF Industries, Inc., Paramus, New Jersey

SOURCE: Industrial Quality Control, vol. 20, April, 1964, pp. 11-12

PURPOSE: To describe an employee indoctrination/motivation/training program using films.

ABSTRACT: In order to remind everyone of the importance of his contribution, the Reliability and Quality Assurance Department at ACF Electronics Division has been operating a film-of-the-month program since June, 1962. Most of the films shown were made by aircraft and missile companies under contract to the Air Force. They are interesting and informative, and show what great care is taken to assure the safety of airborne crews and the success of the mission.

A program such as this can serve, at least in part, to comply with Paragraph 3.5.2 of MIL-R-27542 which states: "The reliability program shall contain provisions to indoctrinate all employees whose work relates to the reliability of the product so that they understand the value of their contribution. Emphasis shall be placed on human engineering aspects of all operations to minimize the degradation of reliability through human error."

Several films are mentioned by title, briefly described, and their area of usefulness is indicated. It is pointed out that a list of twenty films compiled by the ASQC Film Library Committee, together with information on how to obtain them, is found on page 32 of Industrial Quality Control, April, 1964. (Author in part)

REVIEW: This paper contains useful information for those who are concerned with employee indoctrination/motivation/training programs. The listing of films (see ABSTRACT) is similarly useful. Its usefulness could be further enhanced if anyone having suitable films available but not already listed would communicate information on them to Mr. H. J. Jacobson, ASQC Film Library Committee Chairman, Sutherland Jacobson Assoc., 711 State Life Bldg., Indianapolis, Indiana 46204 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1450
Codes 222;840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A special case of percentage sampling

AUTHOR: Ervin F. Taylor, General Electric Company, Philadelphia, Pennsylvania

SOURCE: Industrial Quality Control, vol. 20, April, 1964, p. 13

PURPOSE: To provide a rapid means of assessing the confidence that no defectives exist in a lot when a sample from that lot contains no defectives.

ABSTRACT: This note defines an attribute sampling inspection situation in which the Consumer's Risk, β, is simply (1 - n/N); where n and N are the sample and lot sizes respectively.

It is applicable in a situation characterized by the following conditions:

1. Only one or a few lots are received.
2. Lot sizes are small, so that any reasonable sample constitutes a significant portion of the entire lot.
3. Reliability/quality requirements are relatively high so that no failures can be tolerated if the requirements are to be met.
4. Destructive attribute testing is the only real inspection method which can be used.

The objective of any acceptance sampling procedure in the above situation is to provide some degree of confidence that when no defectives are found in the sample, no defectives exist in the lot. Since the lots involved in this situation may be of "one-of-a-kind," prior experience is of little value.

Fundamental probability theory can be applied to determine the maximum probability of accepting a rejectable lot (one with one or more defectives) when the sample contains no defectives. This is, of course, the "Consumer's Risk." When no defectives are observed in the sample the complement of this "Consumer's Risk" is the degree of confidence that no defectives exist in the lot.

The desired value of β is shown to be (1 - n/N); hence the degree of confidence that no defectives exist in the lot when no defectives are found in the sample is n/N. (Author in part)

REVIEW: This is a neat result, for which the derivation is clearly and concisely presented in the paper. It will be of interest and value to those who are concerned with the destructive attribute testing of "one-shot" devices. Obviously from the result, in order to achieve a high degree of confidence in the situation described, one must test a very large proportion of the lot. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1451
Codes 870;874

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability index verification

AUTHOR: E. P. O'Connell, Hi-G, Incorporated, Windsor Locks, Connecticut

SOURCE: Industrial Quality Control, vol. 20, April, 1964, pp. 14-17

PURPOSE: To review the activities of quantifying, predicting, and measuring maintainability, and to consider their relationship to maintainability verification.

ABSTRACT: The difficulties in quantifying maintainability requirements and in measuring maintainability are discussed. Brief reference is made to maintainability-index development, and to the definitions of maintainability and maintainability verification. Some of the programs of the military services leading to the specification of maintainability are reviewed.

It is concluded that a substantial amount of progress has been made by the various services in the area of maintainability verification. The primary activities have been directed toward the development of general specifications, the main advantages of which are to focus attention upon maintainability considerations during design and development. Subsequent development of more effective prediction procedures should permit prediction and eventual verification of the attainment of maintainability objectives.

Verification in terms of actual performance under end-use environment can also be anticipated in the near future. It is also reasonable to expect that with these activities moving forward, procurement contracts for all the services will include even more effective specification of maintainability in the near future. (Author in part)

REVIEW: This is a rather cursory and general treatment of the subject, which is likely to be of value mainly to those who desire only a bird's-eye view of it. The bibliography could have been more complete. For example, it contains no references on the work of RCA under contract with RADC (see Abstract and Review Serial Number 1441), although brief mention of this program is made in the paper.

(At least one line in the text is missing--at the end of the second paragraph in the third column on page 14.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: EDP or pencil and paper

AUTHOR: G. B. Cohen, Sylvania Electric Products, Inc., Buffalo, New York

SOURCE: Industrial Quality Contol, vol. 20, May, 1964, pp. 8-10

PURPOSE: To indicate that mechanical means may not be the best way of processing failure data.

ABSTRACT: In recent years there has been a trend toward automation of the processing of failure data in the aircraft/missile industries and large manufacturers of electronic equipment. However, there are indications that the amount of effort required to create tab runs is often quite high compared to the amount of corrective action derived from them. In addition, the basic failure reports are often inaccessible when needed for supplementary information. These considerations have led Sylvania Electronic Systems to adopt a manual system for small and medium-sized projects.

The manual system adopted for these projects operates as follows:

1. Failure reports arriving at the Central Reliability Organization are given directly to a professional reliability engineer who is monitoring the particular project on which the failures occurred. He then classifies them by type of problem. He maintains between 10 and 15 types of problems. All of these failure reports are sorted into these categories.
2. When, in his opinion, any of these problem categories require action in an area not under his control, he initiates a Reliability Action Request (RAR). The RAR must be answered within seven days by the responsible organization whether it be a design group, a production department, the Quality Control organization, or any other element of the over-all system.
3. Upon return of the completed RAR, the reliability engineer reviews the intended corrective action to assure that it is adequate, and then continually monitors the program to assure that the corrective action has been implemented and that it is effective.

The advantages of the manual over the EDP system are outlined.

The following are suggested as questions which reliability managers should ask in evaluating their own failure analysis organizations:

1. Are you getting corrective action in proportion to the amount of effort being placed on the processing of failure reports?
2. Are the people involved in this processing of failure reports interested in getting corrective action, or are they more concerned with meeting tab run deadlines?

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

3. Would it not be more profitable to have professional engineers replace the technical clerks presently doing your failure data processing?

4. Do you really need so many people in your failure processing function?

5. Does your failure report give you what you want?

(Author in part)

REVIEW: This is a useful indication of the experience of one company in organizing a failure analysis function. As such, it should be of value to others concerned with the processing of failure data. Individual situations differ, of course, and a system which is effective in one case may not be so in another. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1453
Codes 420;425;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A simple analysis of fatigue data

AUTHOR: E. J. Gumbel, Columbia University, New York, New York

SOURCE: Industrial Quality Control, vol. 20, May, 1964, pp. 14-17

PURPOSE: To present a simple graphical method of estimating the shape and scale parameters of the Weibull distribution.

ABSTRACT: A recent paper (see Abstract and Review Serial Number 499) presented tables of the Weibull distribution and gave graphical methods for estimating the parameters. This paper presents an analogous graphical procedure which dispenses with the use of the tables, and demonstrates a simple method of estimating the parameters which requires a minimum of basic analysis.

The general properties of the Weibull distribution as applied to data on age, number of cycles, etc. are described. The connection of studies of such data with the general statistical problem of extreme values is indicated. The estimation of the shape and scale parameters of the Weibull distribution on the basis of the method of moments, using extremal probability paper and a table provided in the text, is outlined. The only calculated values required are the mean and standard deviation of the number of cycles at failure. A numerical example is given.

REVIEW: As the author has indicated, this paper presents a quick and safe method of estimating the shape and scale parameters of the Weibull distribution, as applied in studies of fatigue, in reliability studies involving numbers of cycles to failure, etc. The method is adequately explained, and the numerical example is helpful.

It should be noted that the brief description of this paper given on page 3 of the magazine is incorrect. It should read: "The shape parameter in Weibull's distribution is estimated from the coefficient of variation of the number of cycles at failure, the scale parameter from a table of the Gamma function." The location parameter is taken to be zero. Another minor error is the fact that Figure 1 in the paper is printed upside down.

Other papers dealing with the Weibull distribution and various aspects of its role in reliability analysis have been covered by Abstracts and Reviews Serial Numbers 320, 437, 499, 749, 751, 801, 848, 1015, 1171, and 1435. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1454
Codes 610;613;810;
831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Systems reliability in the space program

AUTHOR: N. E. Golovin, Office of Science and Technology, Washington, D. C.

SOURCE: Industrial Quality Control, vol. 20, May, 1964, pp. 20-30

PURPOSE: To help broaden the perspectives of those who have had specialized assignments in reliability engineering and management, and to assist in developing a set of conceptual tools for use in approaching reliability problems in general.

ABSTRACT: This paper presents a general development of the conceptual, analytical, and operational bases used for reliability engineering, viewing this discipline as a phase of systems engineering as well as of operations research. The author quotes and comments upon the definition of reliability engineering found in the RADC Reliability Notebook, in arriving at a set of suggested characteristics for the practice of reliability engineering. Reliability engineering, systems engineering, and operations research are described as being fundamentally identical in method and point of view. Some of the basic technical considerations in reliability engineering are summarized. These include the definition of failure, the general definition of hazard function and its implications, the definition of the reliability function for a general system, the problems involved in arriving at explicit subsystem failure rate functions, and the problem of determining confidence intervals on system reliability. Some of the reported approaches to the latter problem are summarized, and a suggested approach is described. Management considerations are discussed in terms of a theory-of-games background.

REVIEW: This is a well-written paper which should accomplish its stated objectives if it receives the thoughtful attention of reliability engineering and management personnel. It merits that attention, especially from those who are inclined to be skeptical about the worthwhileness of a well-conceived and competently-managed reliability effort.

The author is to be commended for keeping his technical discussion above the level of simply assuming that the failure rate is always constant. However, his comment to the effect that "the ... argument ... that there are no 'random' failures because every failure has a cause ... is only a play on words" might well be challenged. If everyone understood the term "random" in this context to have the meaning which he gives for it, his comment would be valid. But such is not the case, apparently, and those who use the above "argument" generally do so because they feel a need to clear up a misconception which they have encountered. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1455
Codes 220;222;224;
823;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability sequential testing

AUTHOR: E. L. Eagle, Chrysler Corporation Missile Division, Detroit, Michigan (present affiliation: Lockheed Spacecraft Organization, Pacoima, California)

SOURCE: Industrial Quality Control, vol. 20, May, 1964, pp. 48-52

PURPOSE: To present a reliability sequential control chart.

ABSTRACT: This paper describes a control chart used to plot reliability test data. Cumulative failures are plotted against time (in units of MTBF requirement). The chart has the usual sequential-test regions: acceptable or not acceptable when the point is outside the "control" lines and no decision when it is within them. The procedure is described and illustrated and the equations of the boundaries are derived in an appendix. The failure process is assumed to be Poisson.

REVIEW: This paper contains a serious error in that the probability levels on which the control chart is based are not correct for a sequential test. They pertain to a single-sample test. This means that the use of the chart will lead to erroneous conclusions regarding the probability levels.

Those who are interested in what this problem really does involve should read Abstract and Review Serial Number 1194. The review, especially, discusses the ramifications of this approach. Square root scales are used there which result in straight lines instead of parabolas. Valid formulas for exact truncated one-sided sequential tests based on the exponential density function are given in the paper covered by Abstract and Review Serial Number 997. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1456 -1
Codes 716;823;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure physics and accelerated testing

AUTHORS: G. Bretts, J. Kozol, and H. Lampert, Spacecraft Department, General Electric Company, Philadelphia, Pennsylvania

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 189-207 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To show that a time-temperature parameter can be introduced to describe aging due to high temperature exposure and to present results of an accelerated test program.

ABSTRACT: The physics of failure is an important part of any reliability program, and can provide pertinent information in several areas. Test planning, and interpretation of test data based upon failure modelling are two major areas. Based upon analytical or experimental results, anomalous behavior can be detected and analyzed. The results of analyses in turn suggest corrective measures for product or process control and techniques for prediction useful in design.

A time-temperature parameter $\theta = T(A + \log t)$ is introduced, in which t represents time in hours, T is absolute temperature, and A is a constant. θ is then a measure of the damage produced in a particular kind of resistor due to thermal aging. The concept of θ has proved valuable in metallurgy. Values of A in the range 15 to 23 are reported in the metallurgical literature; the value A = 15 was chosen here. Two curves of resistance change vs. θ for film resistors are plotted and are reasonably straight lines. In this case the rate process was expected to be largely diffusion. The technique is not applicable when deterioration is highly dependent on random discontinuities or when the relative rates of several processes will change appreciably over the temperature range considered.

The usefulness of physics-of-failure studies in reliability programs is markedly dependent on the availability of information from basic failure physics studies and the establishment of analytical and experimentally demonstrable deterioration models and detection techniques. The more information which can be obtained from basic failure mechanism studies and applied to product or hardware-oriented programs, the greater the gains which can be achieved in system reliability. (Authors in part)

REVIEW: This paper introduces the time-temperature parameter, which is

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

rather well known in the field of metallurgy, into failure electronics. The data seem to fit the concept (that $\log[\Delta R/R_o]$ vs θ is a straight line) nicely over a reasonable range. (R is resistance.) The deviations at each end are also reasonably explained.

If in fact the relationship is a straight line then

$$\ln(\Delta R/R) = m\theta + b,$$

where m and b are independent of θ (and thus of T and t). The authors imply that a straight line is predicted by the Arrhenius relationship and proceed to derive, in two places, an incorrect formula. (In a private communication, the authors have supplied the correct equation.) The incorrect equation in the paper is equivalent to

$$\theta = [Q \ln(\Delta R/R_o)]/R_g$$

where Q is the activation energy and R_g is the gas constant. The correct equation is

$$\ln(\Delta R/R_o) = \theta/T - Q/R_g T;$$

this is not equivalent to the straight line equation above due to the fact that $m = 1/T$ and $b = -Q/R_g T$, neither of which is independent of T and thus of θ. If T may be presumed to be constant here, it may as well be presumed constant in θ and then the curves prove nothing about θ.

No mention is made of how to calculate θ when T is a function of t, as it is in several of the data points (i.e. step-stress).

The discussion of the physics of parameter drift and change are adequate, although not extensive for both the resistors and transistors. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the extrapolation of accelerated stress conditions to normal stress conditions of germanium transistors

AUTHOR: Jayne Partridge, Staff Member, Instrumentation Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 208-225 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To show that failure modes in germanium transistors are different at normal and high stress and thus to point out that accelerated testing is misleading in this case.

ABSTRACT: Accelerated stressing has become a popular method of evaluating high reliability devices in short periods of testing time. However, the convenience of accelerated testing should not be the sole criterion for its use. The modes of failure generated by normal (within rating) and accelerated (exceeding rating) stressing should be compared before failure rates created by accelerated stressing are accepted as valid.

It has been found for moisture gettered PNP germanium mesa transistors that the predominant modes of failure created during accelerated stressing are different from the predominant modes of failure created during normal stressing. During accelerated unpowered thermal stressing, parameter changes are exactly opposite to parameter changes during normal unpowered thermal stressing. The direction and irreversibility of parameter changes, the dependence of amount of parameter change on the stabilization-bake temperature and internal package vapor pressure, and a good fit of h_{FE} decay to Wallmark's equation,

$$(1/h_{FE}) = C_1 \, e^{-C_2/T} \, t^{1/3} + C_3,$$

all point to oxidation of the germanium surface. The "activation energy" as determined from the above equation is discussed. Oxidation of the germanium surface is negligible at temperatures less than stabilization-bake temperatures.

Testing at high power produced several predominant failure modes not observed during normal power stressing. Electrical overstressing characterized by lead wire melting and junction shorting were first-order failures. Failures by junction shorting through the bulk were dependent on reverse collector voltage as well as power. The failures were attributed to operation in a

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

negative resistance mode. During lower-voltage accelerated-power stressing, parameter degradation identical to parameter degradation created during accelerated unpowered thermal stressing was observed at the emitter junction only. As has been found with normal stressing, unpowered thermal stresses in general do not create the same failure modes or parameter changes as the combination of reverse voltage and power. Only as reverse bias is decreased do parameter changes approach those of pure thermal stresses. (Author in part)

REVIEW: The author clearly illustrates the danger of blindly using accelerated tests. The report is quite detailed and well documented. Unfortunately (although no reflection on the paper, which is good), the conclusion is a negative one and much of the work is not directly applicable to other components.

In a private communication the author has said that an additional intended purpose of the paper was to compare failure modes created during accelerated operational (power) stressing to those created during accelerated thermal (unpowered) stressing. She has also made the following comments: "Most of the results of the accelerated operational (power) stressing were known to be applicable to virtually all transistors made at the time (of preparation of the paper).... It has since been established that the accelerated operational results are still applicable to most transistors including those in integrated circuits. The important conclusions are that when a transistor is operated in an accelerated power mode such that the emitter is forward biased and the collector reverse biased, the collector junction experiences the combination of voltage and thermal stresses which creates a failure mode common to most transistors, and the emitter junction experiences essentially only a thermal stress." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1458
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction of functional electronic block performance through localization of malfunctions

AUTHORS: W. J. Lytle, J. W. Merck, J. W. Dzimianski, and S. M. Skinner, Air Arm Division, Westinghouse Electric Corporation, Baltimore 3, Maryland

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 226-244 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To evaluate the use of secondary electrical properties for indicating the reliability of microelectronic devices.

ABSTRACT: A guard ring diode structure was fabricated in silicon and examined by contact photoresponse and by the dependence on stress of low level V-I characteristics. The photovoltaic responses of the diodes were as expected with two exceptions and a stress dependence of the forward V-I characteristic was observed. The different response in the case of two out of the nine diodes in the tests is interpreted as a sensitive indication of the failure possibility. These two diodes were known to be defective.

REVIEW: The use of tests of the secondary electrical characteristics of devices as reliability indicators is interesting although not new. For the seven diodes which were not defective both the photovoltaic response and the stress dependence of the V-I characteristics are much as expected. The two other diodes exhibited odd characteristics often found in laboratory samples of silicon structures. These are difficult to interpret due to incomplete knowledge of the fabrication process and structure.

This paper would have been strengthened by a more complete description of the experimental techniques. The illumination and the area covered by the light are important for the photoresponse measurements. They were not given nor was the circuit used in the measurements. The magnitude of the stress effect on diode V-I characteristics is very sensitive to position of the probe with respect to the junctions, so no value should be placed on the absolute magnitudes of these effects. The oscilloscope curves are difficult to interpret on the basis of the information given. Is the modulation on the photovoltage AC pickup? In summary, this is a promising preliminary experiment but both the structures and test methods must be refined before their evaluation as reliability indicators can be made. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1459 -1
Codes 773;775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of the Electron Microprobe Analyzer to the study of silicon switching diodes

AUTHOR: Paul Pietrokowsky, North American Aviation, Inc., Autonetics, Anaheim, California

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 245-267 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To illustrate the usefulness of the Electron Microprobe Analyzer as a point analysis tool for semiconductor technology.

ABSTRACT: In the Electron Microprobe Analyzer a focussed beam of electrons interacts with a small surface region of the material being studied. Information is obtained on the nature of the material from the reflected electrons, the specimen current, and the characteristic X-ray emission. Both scanning and point analysis modes are used. As an illustration of the use of this technique, the alloys present in silicon diodes fabricated by two different processes were studied. Different intermediate phases of the alloys were identified, some of which are not desirable for the diode structure.

REVIEW: This paper describes the use of an electron beam for analysis of device structure in a mode somewhat different from that most recently described by Westinghouse (see Abstract and Review Serial Number 1310). The work described here involves both point and scanning beam analysis using the characteristic X-ray emissions as well as the reflected and absorbed electrons as affected by the composition of the material. The Westinghouse studies were on structures, in which electric fields affected the secondary electron current intensity. Essentially different types of information result from these two studies.

The microprobe analyzer results are, in the author's words, "of an exploratory nature." The data presented indicate a capability for determining the relative amount of a given material in an alloy as a function of position by observing the intensity of the characteristic X-ray emission. There is a question in this reviewer's mind as to the actual interpretation of the results as shown. Does the X-ray emission intensity vary because the beam current varies or do they both vary because of the same phenomena? The author states that "A review of the physical principles which are of importance in quantitative techniques is beyond the scope of this paper," but at the same time draws conclusions which re-

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

quire more justification on physical principles than is indicated.

In general, perhaps because the techniques are relatively new, there is a fuzziness in the presentation. Two types of diodes are studied extensively without any identification of them. The data given in Figures 10, 11, and 14 are incompletely identified. Generally, the technique looks promising, but one hopes that, as it is improved, there will be a corresponding improvement in the presentation and interpretation of the results. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1460 -1
Codes 431;711;714;
775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Burst noise in semiconductor devices

AUTHORS: W. Howard Card and Anton Mavretic, Syracuse University, Syracuse, New York

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 268-283 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To explore the relationship between excess noise and the drift of device parameters.

ABSTRACT: Low-frequency excess noise comprises two components which we call clean noise and burst noise. Because burst noise is closely associated with chemical processes and occurs in transistors which have parameter drift, we suspect a correlation between burst noise and drift. The observation that burst noise is a statistically nonstationary random process suggests a correlation with irreversible chemical processes and breakdowns.

This paper reports several systems for measuring low-frequency noise. Important features of these measuring systems are the following: (1) A strip-chart recorder is used with a broad-band amplifier and detector in order to distinguish clean noise from burst noise. (2) A magnetic-tape recorder used with a spectrum analyzer and an amplitude-distribution-function analyzer permits useful measurements of nonstationary processes. (3) An electronic counter permits accurate nonsubjective long-term averages of the spectrum analyzer indication.

We postulate two interpretations for burst noise: (1) It is a non-stationary fluctuation in the level of clean noise. (2) It is the superposition of clean noise and uncorrelated voltage steps from a nonstationary process. For example, drift in a resistance value may result from a preponderance of voltage steps (hence resistance changes) in one direction. These postulates require further investigation.

Preliminary attempts at finding correlations between parameter drift and burst noise are hindered by the absence of quantitative measures of burst noise. (Authors in part)

REVIEW: This paper is an intensive continuation of a portion of a previous presentation by one of the authors (see Abstract and Review Serial Number 1374). The work is also related to that described by J. G. Curtis (see Abstract and Review Serial Number 1371), in

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

that excess current noise is investigated as a tool for predicting component reliability.

No firm relationship between h_{FE} drift and excess noise is established here, but recognition of the distinction between two components of excess noise could be an important step toward such a relationship. The component of excess noise, called burst noise by the authors, is shown to originate from nonstationary processes and has a drastic sensitivity to surface contamination. That a relationship exists between device electrical parameters and some form of noise measurement seems almost inevitable. The sensitivity of this relationship is perhaps the more important question which is as yet unanswered. This investigation appears quite likely to provide some answers shortly. ##

Serial Number 1461 -1
Codes 782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Localized thermal effects in silicon power transistors

AUTHORS: R. M. Scarlett and W. Schroen, Shockley Laboratory of Clevite Transistor, Palo Alto, California

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 285-303 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To relate hot spot formation and second breakdown to thermal instability and to describe the damage to power transistors caused by these thermal effects.

ABSTRACT: Two origins of thermal instability in power transistors are temperature coefficient of the emitter junction and thermally-generated current flowing into the base region from the collector ("thermal runaway"). Structural resistances sometimes stabilize the current increase which is induced by the first mechanism, but are not very effective in limiting the current increases due to the second mechanism. These two mechanisms together cause the development of hot spots and eventually second breakdown behavior. While the region of second breakdown usually occurs near the center of the hot spot which is developed prior to onset of second breakdown, this is not true for all transistors. To account for such deviations, local defects are presumed to initiate second breakdown in those cases in which it occurs at points far removed from the hot spot.

The first part of this paper presents experimental evidence for the build-up of temperature under pulsed operation and the consequent development of hot spots and occurrence of second breakdown. The distribution of current among the various fingers of a power transistor is mapped by a reference probe and by temperature-indicating paint.

The second part of the paper examines the damage caused by hot spot development and by second breakdown. From hot spots alone, damage is seldom detected by electrical measurements, but visual observation reveals a discoloration of the aluminum contact metal in the hot spot area. After removing the aluminum dense pitting of the silicon surface can be seen and indicates that further reaction has occurred between the aluminum and silicon. The effect of second breakdown is to internally-short the emitter to the collector.

REVIEW: This paper is the latest in a series by the Shockley group dis-

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

cussing thermal instability in power transistors (see Abstracts and Reviews Serial Numbers 1370 and 1378; an earlier paper in the series is cited below [1]). While the description of thermally-induced breakdown is the same as before, several details are dramatically emphasized. The plots of finger current as a function of collector voltage clearly show the changing current distribution during hot spot formation and second breakdown. For the transistor in which a defect is thought to initiate a second breakdown at a site not included in the original hot spot, the finger current data are particularly interesting.

The photomicrographs showing regions of damage caused by thermal instability are extremely good and informative. In a few pages the reader sees a fairly complete, graphic presentation of the problem. The solution, however, is not discussed, although the use of four separate wires to contact the emitter stripe may represent a solution of a sort. Methods for minimizing thermal instability and the damage caused by it are not given.

REFERENCE: [1] R. M. Scarlett and W. Shockley, "Thermal instability in power transistors," presented at the Solid State Device Research Conference, Durham, New Hampshire, July, 1962 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1462 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure mechanisms in semiconductors

AUTHOR: H. Stuart Dodge, Burroughs Corporation, Burroughs Laboratories, Paoli, Pennsylvania

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 304-327 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To describe a program and some techniques employed in component failure analysis, particularly as it is applied to semiconductor diodes and transistors.

ABSTRACT: A substantial reliability effort with emphasis on semiconductor devices has over several years resulted in increased system reliability and effective extension of the life of computers already in the field. The essential element in the failure analysis is a close physical examination of failed components and comparison with good components. Special techniques have been developed for this analysis. Among the failure mechanisms noted are surface contamination, purple plague, improper etching during fabrication, and improper alloying. While some of these are results of the rapid application of new techniques to semiconductor devices without sufficient experience to indicate reliability, a number of failures are attributed to mistakes. These mistakes range from shipment of rejected components to sloppy workmanship.

REVIEW: This is an interesting and informative exposition on very practical sources of component failure. While the examples given may be mavericks, such causes of failure cannot be tolerated in modern electrical systems. The inherent failures are trouble enough. When one sees diodes which are redundant by accident rather than by choice, the quality control on the production line is deficient. There are a few minor comments in this paper which show that those doing failure analysis of components should become more familiar with the components. For example, on page 309 it is suggested that any parameter change on a semiconductor device which occurs when the device surface is cleaned indicates a contaminated surface. This is incorrect. Very few semiconductor devices do not change their characteristics with surface treatment, regardless of the initial surface condition. There are device manufacturers who would take exception to the classification of planar devices as mesa type devices. The statement made on page 312 that oxide coated devices are theoretically impervious to surface contamination is not an established fact. These minor points should not detract from the overall presentation. Those who are concerned

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

with semiconductor device failure will find that the information here is not only interesting but suggests the desirability of being more critical of manufacturing techniques.

In a subsequent private communication the author has commented as follows on the desirability of establishing feedback with the manufacturer: "It has been our experience here at Burroughs that once the manufacturer is aware that a program of this sort (failure analysis) is in operation, he tends to be selective in the quality of components shipped, especially in a case where there are several vendors for the same product." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1463 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the degradation of gallium arsenide tunnel diodes

AUTHOR: R. L. Anderson, Department of Electrical Engineering, Syracuse University, Syracuse, New York

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 328-337 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To show that the deterioration rate in gallium arsenide tunnel diodes is proportional to injection current.

ABSTRACT: The usual failure mode observed in GaAs tunnel diodes is associated with high forward bias and is manifested by an increase in valley current and a decrease in peak current with time. Although in a given junction, the rate of degradation is a monotonically increasing function of forward current, few quantitative generalizations have been made. It has been postulated that the deterioration results when the energy released by recombination of injected carriers is given to an impurity atom and Frenkel defects are created. The interstitial atom (ion) then diffuses, but the electrostatic barrier at the junction causes a "pile up" of these ions. The ions reduce the doping at the edge of the transition region and also create "band-gap" states. The peak current is then decreased by a widening of the transition region, while the valley current may decrease for the same reason or may increase due to tunneling to (or from) the band-gap states.

Evidence is presented that the deterioration of GaAs tunnel diodes is caused by, and is directly proportional to the true injection current, which, although masked by excess current, does exist. This is in agreement with the above postulate. One result is that, with sufficient deterioration, the diodes fracture due to accumulation of defects. This is observed.

REVIEW: It is shown that the deterioration rate in gallium arsenide tunnel diodes is proportional to injection current, if the limited data which are presented are a valid representation of the phenomenon. The title of this presentation implies a more comprehensive treatment than is given and the explanation of the deterioration of GaAs tunnel diodes is far from clear. For example, Shibata (Japanese Journal of Applied Physics 3, May 1964, p. 262) has shown the existence of a double peak in the I-V characteristic which appears during the deterioration process but which was not reported in these measurements. The mechanism supported in this article was postulated by Gold (IRE Transactions on Electron

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

Devices ED-8, 428, 1961) and is but one of several mechanisms which have been proposed for the deterioration process. The field aided diffusion suggested by Longini (Solid State Electronics 5, 127, 1962) is another for which supporting data have been given.

The experiments described in this paper are good, the results are interesting and they will, no doubt, contribute to the understanding of the GaAs deterioration problem. The data presented are not sufficient, however, to clarify the mechanism involved in GaAs tunnel diode deterioration. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1464
Codes 716;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The aging mechanisms of metal film resistors

AUTHORS: John J. Bohrer and Charles W. Lewis, International Resistance Company, Philadelphia 8, Pennsylvania

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 338-348 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To review the physical theory of the aging of thin film resistors.

ABSTRACT: The resistance of a thin film depends upon the resistivity and the geometry of the film. For a homogeneous film (resistivity the same throughout) the change of film resistance with time (aging) results primarily from the geometrical reduction of the film thickness by oxidation or from a decrease in resistivity brought about by the annealing of defects. A time-independent temperature coefficient of resistance is indicative of purely geometrical aging but is not a necessary condition, since the resistivity itself generally varies with film thickness. In non-homogeneous alloy resistors, phase separation alters the resistivity and becomes an additional aging mechanism. In extremely thin films gaps tend to appear between the film particles and eventually create discontinuities in the conducting path, making tunneling the major mechanism of current flow. All these aging processes--oxidation, annealing, and phase separation--are proportional to $(\text{time})^{\beta}$ where $\beta < 1$. If failure is defined as a specified change in resistance, life may be extended by pre-aging.

REVIEW: This paper is a continuation of a previous presentation by the same authors on the same topic (see Abstract and Review Serial Number 1340). Again the discussion is general and constitutes a summation of the established theory which they believe is useful in understanding the aging mechanisms of thin film resistors. Space limitations prevent them from delving into the physics in any detail but ample references are provided for the interested reader.

The ambiguities noted in the review of the previous paper have been rectified. An α_o is missing from the right hand side of Equation 16. Figure 1 would probably best be modified or omitted because it turns out to be an "optical puzzle" which can be interpreted in more than one way--and the description in the text is quite adequate without the figure. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1465
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure mechanisms in traveling-wave tubes

AUTHORS: R. A. Hein and J. S. Needle, Sylvania Electric Products Inc., Mountain View, California

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 349-360 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To show how residual gases in a traveling-wave tube affect its life.

ABSTRACT: Evidence presented in this paper provides a model for the effect of residual gases on the activity of an oxide-coated cathode. The results emphasize the concept that the total number of ions striking the emitting surface is a significant parameter which affects cathode activity. The hydrogen molecule becomes more suspect relative to cathode damage than has previously been considered.

The evidence suggests that cathode life can be lengthened by minimizing residual hydrogen in a vacuum tube, by preventing ions already present from striking the cathode surface (by altering the potential profile of the tube) or, where possible, by the use of a cathode which is less susceptible to this type of degradation than the cathode type discussed in this paper. (Authors)

REVIEW: This is a continuation of the work presented in the papers covered by Abstracts and Reviews Serial Numbers 1368 and 1369. The conclusions of the authors appear reasonable from the evidence they present. Now, hopefully, longer-life tubes can be designed and built using this knowledge. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Aging characteristics of field effect thin film active devices

AUTHORS: Klaus K. Reinhartz, Virginia A. Russell, David L. Stockman, W. J. van der Grinten, and Warren L. Willis, General Electric Company, Electronics Laboratory, Syracuse, New York

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 27-33

PURPOSE: To describe the effects of humidity, temperature and electrical stresses on a group of thin film field effect triodes.

ABSTRACT: Realization of the full potential of the thin-film approach to microelectronics hinges upon the ability to fabricate stable and reproducible thin film active devices. Toward this end a study has been undertaken of the failure modes of such structures. For the initial phase of the study the CdS thin film triode with SiO insulation was used as the test device. The performance indicators, gate voltage and transconductance for constant drain current and voltage, were calculated from measurements of drain characteristics and gate capacitance.

A control group of devices was stored for over six months in a room-temperature, dry-argon atmosphere with no electrical stresses except as necessary for periodic measurement of performance. No degradation was detected. Devices were then subjected to temperature, humidity and electrical stresses taken separately; all parameters, except the stress, were the same as at storage conditions.

Performance was highly sensitive to relative humidity (RH). A level of 1% RH produced little change; however, failure generally occurred at 30% RH after several days of exposure. The changes in transconductance were somewhat reversible. At 80% RH the insulating layer peeled away from the semiconductor after a few hours, resulting in permanent failure.

Temperature stresses were carried out in the range 50°C to 121°C. The transconductance increased approximately linearly at a rate of less than 10% per 50 days. The gate voltage approached a value several times the pre-test value with a time constant on the order of hours.

Under electrical stress with constant drain power, the transconductance remained essentially constant. The gate voltage required to maintain constant drain power increased reversibly with varying rates to a steady value in about 30 days.

The findings indicate that changes in device performance are

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

brought about by changes in the semiconductor surface conditions under the three types of stress. Bulk properties of the CdS film appear rather constant.

REVIEW: This report is the first in a basic study on failure mechanisms at surfaces and interfaces in thin film devices. Those people involved with the fabrication of such structures should find it interesting. It is well-written, and details are complete with one notable exception. No mention is ever made of the number of samples tested so that the reader scarcely knows how much faith to put in the findings.

The paper is admittedly only an introduction in its area, and the results should not be considered exhaustive. In this connection the authors point out that some of their findings disagree with those for similar devices fabricated elsewhere. Clearly a great deal more study is necessary before strong conclusions can be reached. A useful addition to the paper would have been an indication of what sort of follow-up could be expected.

In a private communication, the first author has commented as follows: "I would like to mention that in the average five samples from different production runs were used for each stress test. Recently we have submitted one paper for publication in the Microelectronics issue of the Proc. IEEE and one for presentation at the Third Symposium on Physics of Failure in Electronics, which will give further information on our work in this area." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1467 -1
Codes 713;720;835;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fabrication and reliability of thin film crossovers and terminations

AUTHOR: A. E. Lessor, Jr., Components Division, IBM Corporation, Owego, New York

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 48-53

PURPOSE: To report findings concerning failure modes in a typical microcircuit crossover and to make recommendations of optimum processes for fabrication.

ABSTRACT: Losses and unreliability of crossovers (of conductors) in integrated thin film circuits have been at least halved by incorporating two techniques in their fabrication. Electrolytic micropolishing of the lower conductor removes the sharp edges, thereby allowing the insulating film to assume a nearly uniform thickness at the crossover. A two-step deposition of the insulating layer with deliberate misregistration of the mask during one step yields a smoother contour than a single-step process. The thickness of the upper conductor then becomes more nearly uniform.

Insulation failures and their relation to fabrication procedures for the chrome-copper, silicon monoxide, chrome-copper crossover were studied. The failures fall into three categories. Low resistance (< 10 ohms) stable shorts are caused by mechanical defects such as pinholes and separation from substrate. High resistance (10^3 to 10^{12} ohms) unstable leakage paths result from conduction through moisture accumulated on contaminated substrate surfaces and in porous hygroscopic insulation layers. "Delayed action high ohmic unstable shorts" originate in insulation damaged by expansion of trapped moisture during soldering or bonding operations.

Reliability is affected not only by the individual process parameters but by their interaction as well. Careful note must be taken of the possible effect of each operation on a previous one. The most important process parameters and their relations to failure are as follows: Excessive residual gas pressures may cause oxidation of films and high-resistance copper layers. Incorrect substrate temperatures cause rough or mechanically unsound films. High deposition rates may allow ejection of particulate matter from the source. Poor crossover geometry may give high resistance conducting paths, thin spots in insulation, and sharp corners which create high electric fields.

REVIEW: This paper is essentially a presentation of the results of a study

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

of insulation failure in a typical crossover structure. The failure modes are neatly categorized and are related to the process parameters. No description of the actual mechanics of the study is included, but the paper contains such an air of authority that one readily assumes that it was well conducted. The findings and recommendations for optimum processes are given in detail except for identification of the substrate material. (In a private communication, the author has indicated that the substrates were Pyrex 7740 polished to 300A.)

The report suffers from some lack of organization. Careful attention to sequence of material, paragraph formation and use of headings could transform it into an excellent paper. ##

Serial Number 1468
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure modes in thin film circuits

AUTHORS: P. Smith, M. Genser, and R. Serrette, General Precision Aerospace, Little Falls, New Jersey

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 70-75

PURPOSE: To describe a study of failure modes in thin-film circuit modules and to make recommendations for improvement.

ABSTRACT: A study was made of the failure modes in thin-film circuit modules. Emphasis was placed on film-resistor failures and circuit failures. A thermal map was plotted for a substrate containing a flip-flop circuit operating in an ambient of 100°C. A hot spot was found to exist. Resulting changes in resistance greater than 0.5%, considered failures, were common. Brown discolorations, believed to be residual flux, were also noted.

Special glass substrates containing resistive films covering either 20% or 60% of the substrate surface area were constructed. The films were overstressed to 2 watts per sq. in. (presumably of substrate area). One substrate with the smaller film area fractured almost immediately while none with the larger area fractured during a 100-hour run. Resistance values changed by 0.5% to 0.8%. Encapsulated substrates containing assembled components were stressed at temperatures from 100°C to 180°C for 1.5 hours. Examination of modules having circuit failure revealed such primary and secondary failure modes as leads detached from components and damaged SiO.

Conclusions include the following: (1) Thermal analysis of substrate layouts should be done at the design stage to eliminate hot spots. (2) The use of solder connections should be minimized. (3) Cased transistors are preferred over tab types. (4) Metal cans should be used instead of plastic encapsulants.

REVIEW: A hodgepodge of experimental procedures and results have been thrown together in this paper. It is characterized by vague writing, omitted information and unfamiliar methods of presenting data. It gives a very poor impression of the quality of the work.

The authors, in a private communication, have pointed out that the paper itself is an abstract of a more comprehensive report which was to have been delivered to individuals possessing expertise in the specific areas of technology covered. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1469
Codes 711;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dielectric breakdown in solid electrolyte tantalum capacitors

AUTHORS: L. F. Howard and A. W. H. Smith, Mallory Capacitor Company, Indianapolis, Indiana

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 187-193

PURPOSE: To propose a model for breakdown and subsequent healing in the dielectrics of solid electrolyte tantalum capacitors.

ABSTRACT: Catastrophic failure of solid-electrolyte tantalum capacitors results from localized breakdown of the tantalum oxide dielectric film. During breakdown the capacitor leakage current rises to a relatively constant value typically in one millisecond. Often the device will exhibit healing as evidenced by a subsequent drastic reduction of current.

The mean breakdown voltage was found to increase with increasing temperature, and a step-stress analysis showed that it also decreased with increasing time intervals of voltage application. Absence of pre-breakdown noise and consideration of the oxide band gap preclude the likelihood of either avalanche or field emission. Since the thermal-breakdown equation predicts even shorter times than those observed, the R-C time constant is the limiting factor.

The increase of the Tafel slope dV/d(lnI) in the healing process apparently results from an increased series resistance at one of the film interfaces. This phenomenon can be explained by decomposition of the manganese dioxide to a lower, insulating oxide at the high temperatures generated by the leakage current.

REVIEW: This clearly-written paper presents some interesting hypotheses concerning breakdown and subsequent healing in tantalum capacitors. If the hypotheses are proved correct, the healing effect could be used to great advantage during manufacture to provide higher yields and greater reliability.

Two minor errors appear: dt/dt is written for dT/dt in equation 1, and a reference to equation 1 on page 189 is meant to pertain to equation 2. Inclusion of references for the equations discussed would have been helpful. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1470
Codes 716;782;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Storage of electronic components and equipment

AUTHORS: R. F. Ficcki and M. Raphelson, Communications Systems Division, RCA, Camden, New Jersey

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 225-237

PURPOSE: To provide a summary of the available data on failure of stored electronic components and equipment and to point out the urgent need for serious study of the problem.

ABSTRACT: Toady's philosophy of defense, under which "stored" systems must operate instantly upon command, requires quantitative information on reliability and failure rates of stored electronic parts and equipment. On the basis of the very small amount of available data, the failure rate for items stored under nonsevere conditions appears to be roughly 1/1000 of the operating failure rate. To obtain more precise information, the following studies are urgently needed: (1) determination of primary cause of failure and strength limitations of individual components, (2) investigation of existing equipments that have been in the field for at least five years, and (3) a detailed study of components under conventional testing procedures to provide a control on data from (1) and (2).

REVIEW: The authors have done as well as could be expected with the meager resources available. The data on the subject of storage have been summarized and a few shaky conclusions have been sketched. The main contribution of this paper is in pointing out what needs to be done. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1471
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An inventory of intrinsic sources of chance failures in electronic parts

AUTHOR: John A. Connor, Astro Reliability Corporation, Sherman Oaks, California

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 238-250

PURPOSE: To discuss the reasons why things fail and how the failure probabilities of parts can be calculated from the data available.

ABSTRACT: There are eight primary functions for parts: electrical connections, electrical power dissipation, electrical insulation, dielectric and magnetic energy storage, rectification or gain, structural functions, and kinematic functions. These are analyzed carefully by examples. All of them must be taken into account in considering the failure modes of a part. This is why simple extrapolation of failure rates is not always proper since the different failure modes extrapolate differently. For example, dielectric failures in a capacitor extrapolated according to the usual temperature-voltage laws will not usually be correct because mechanical connection failures, etc. have not been considered. A table is given of sources of "chance" failures; an equation for modeling failure rate is displayed, together with a comprehensive check-list of risk factors affecting part failure rate synthesis.

The methods of estimating failure rates from field tests, laboratory tests, etc. are discussed.

REVIEW: The paper contains many worthwhile ideas, but the manner of presentation makes the reading of it rather tedious. The failure rate formula is displayed, but not justified in any detail. The concept of "chance" failure is used throughout the paper; this is a poor choice of words since each failure is presumed to have a cause. This point is discussed more completely in Review Serial Number 1216, which covers another paper by the same author. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1472 -1
Code 843

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Computer screening technique for higher reliability

AUTHOR: L. V. Ingle, Delco Radio Division, General Motors Corporation, Kokomo, Indiana

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 251-257

PURPOSE: To describe a computer program which can be applied to screening potential failures from any group of components using an outlier technique.

ABSTRACT: The reliability of a product can be improved by removing the potential failures. The approach described in this paper is designed to reveal the initial parameters and truncation levels required to predict future application failures. The basic assumptions underlying the system are (1) deviates from the optimized production processes of a high quality component will reveal themselves as outliers from the bulk of the population and, (2) these deviates possess a higher probability of application failure than the balance of the population.

The program is readily applicable to any component where initial parameters can be measured numerically and later failure data are available. The program establishes frequency distributions for any sixteen three-digit signed measurements with frequency cell intervals of the analyst's choosing. It is, therefore, possible for someone who may be relatively unfamiliar with a component to make a quick literature search, select a promising group of potential failure-predicting parameters, and determine their effectiveness quickly and at low cost.

The screening method applied by the computer simulates a tightening of an upper or lower limit in attempts to screen out or remove the failures while leaving the bulk of the population unaffected. It is, therefore, called an "outlier screening program" as it is based upon the hypothesis that deviates from the optimized process specifications of quality production are inherently weaker and, hence, more susceptible to failure. The screening program utilizes the widely available IBM 1401 computer and requires approximately 5 minutes to determine 5 truncation levels on 100 units having 16 parameter readings each. Over 50 different electrical parameters were processed through the program on power transistors. Examples of effective and ineffective screening distributions encountered are presented and the reasons for their success or failure are discussed. Since the success of any removal program hinges upon the costs and savings involved, a discussion of the optimum economic screening level is presented.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

The approach presented has several limitations: it will not screen a distribution from the high and low sides simultaneously or remove a massive failure cell from the center of the population. Interaction is not handled (e.g., a high value of parameter A and a low value of parameter B predict failure), but the reader is referred to the linear discriminant model presented by Battelle Memorial Institute which has been programmed for four parameters [1]. Hopefully, the technique will assist in evaluating a large number of parameters on any component easily and the decision rule presented will contribute to the selection of the most economic screening plan. (Author in part)

REFERENCE: [1] R. E. Thomas, A. R. Fish, H. M. Braner, and W. E. Chapin, Development of a Methodology for Screening Electronic Parts by Using Linear Discriminants, Electronic Component Reliability Center, Battelle Memorial Institute, Columbus, Ohio, January 1962

REVIEW: This is a well-written paper. The proposed approach, its advantages, and also its limitations are clearly presented. The method should be quite useful in situations in which an effective failure-predicting parameter is found to exist. Establishing this existence will require adequate failure data as well as initial measurements on the relevant parameter or parameters. In specific situations this may not always be accomplished "quickly and at low cost." In fact the analyst should expect to investigate some "blind alleys" before arriving at a suitable choice of parameter. However, when an effective failure predictor is found, the approach should be well worth the time, effort, and cost. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1473 -1
Codes 424;822;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Case studies of the decreasing failure rate phenomena in mixed populations

AUTHOR: F. R. VanWagner, Reliability and Serviceability, IBM General Products Division, Development Laboratory, San Jose, California

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 258-273

PURPOSE: To describe an investigation of the possibility that observed decreasing failure rates in electronic components may be due to mixed populations.

ABSTRACT: One of the more intriguing phenomena of component life studies is the "decreasing failure rate," DFR, frequently detected when time-to-failure distributions are plotted on Weibull probability paper. Since Weibull plotting is a very common analytic method, many engineers have come to accept the decreasing failure rate for transistors as gospel. One is led to assume that somehow each transistor, like cheese, gets stronger with age.

Critics of this remarkable viewpoint, mindful of the fantastic life times which would result if a device failure rate actually did diminish with age, have suggested mixed populations as a cause. If the population were not homogeneous, but contained a subgroup of "weak-sisters," a decreasing failure rate ought to be observed. It has been shown that any mixture of exponential probability density distributions always exhibits a DFR. Perhaps, then, a mixture of distributions involving slight wear-out might also exhibit a decreasing failure rate.

This paper describes some studies of the properties of mixed distributions, effected by computing the theoretical properties of some mixtures and simulating some actual mixtures by creating "life test" data on an IBM 7090. The following conclusions are drawn:

1. The case for a true DFR, at least in early component life, is far stronger than was supposed by those who thought the apparent DFR was caused by the device population being a mixture of subgroups, each of which had a constant failure rate. But the case for DFR is not nearly as solid as other workers seem to assume, because of the possibility of undetected mixtures.

2. Gross errors may result from estimating Weibull parameters either from small sample life studies ($N < 50$) or from studies in which a very small percentage of the devices have failed ($< 5\%$ if $N \approx 400$ or $< 3\%$ if $N \approx 1000$).

3. Failing to detect a mixed Weibull when it exists <u>may</u> lead to extremely large errors in estimates of mean time to failure or system reliability. Further, device development work, or any

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

field replacement and service strategy based on the device failure distribution, may be self-defeating if a mixed Weibull has been mistaken for a simple Weibull.

4. It is virtually impossible to detect (by plotting) mixtures of Weibull distributions having the same or similar shape factors (Beta).

5. Life studies should be prolonged whenever possible so that we can tell when wear-out modes commence to show.

6. Failed parts should be examined to determine cause and mode of failure. In general, one can expect each distinct mode to evidence itself in a distinct Beta--if we can correctly classify the failures.

A need for developing an analytical method of detecting mixtures through the use of order statistics is cited. The literature on the detection of increasing and decreasing failure rates, testing for departures from exponentiality, and the consequences of such departures is reviewed briefly. The need for further work on the Weibull and mixed distributions is indicated. Twenty-four pertinent references are cited. (Author in part)

REVIEW: This is an excellent paper on a worthwhile topic. It should be read by all enthusiasts of life-test data analysis. It can also be a spur to theoretical work in the area of mixtures of distributions.

Additional cautions to after-the-fact curve fitting are:

1. Almost any data can be fitted by anything if enough adjustable parameters are available.

2. There is nothing magic about any particular distribution. They are all just more or less adequate mathematical models which may have some use. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1474
Codes 552;813;823;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Industrial adaptation of the time dependent failure rate

AUTHOR: Ki Punches, Motorola, Inc., Military Electronics Division, Scottsdale, Arizona

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964, pp. 274-278

PURPOSE: To explain the time dependent failure rate, provide evidence for its existence, discuss its effects on the electronics industry, and outline a course of action to incorporate it as a useful tool.

ABSTRACT: Recent data on electronic parts and equipments strongly demonstrate the existence of a time-dependent failure rate. Though some part types may be proved to have constant or increasing failure rates, the predominant evidence to date indicates that a decreasing failure rate is most likely. A commonly-used indicator of failure-rate variation is the Weibull plot of percent accumulated failures as a function of failure age. This usually linear curve indicates an increasing, constant or decreasing failure rate by a slope greater than, equal to, or less than unity. A slope of 0.5 is typical for referenced data.

As a result of erroneous assumptions regarding failure rate, the component parts manufacturer will be likely to extract wrong failure rate inferences from his life test data, and the equipment manufacturer will have inaccurate reliability estimates. Efforts should be applied throughout the electronics industry to measure failure rate characteristics of electronic parts and to incorporate such findings into the design of equipments and systems and the prediction of reliability. (Author in part)

REVIEW: This paper presents a somewhat simplified view of the highly complex problem of failure rate behavior with time. The recommendation of the Weibull method for detecting failure rate variations should, however, contain some hint of the hazards and shortcomings involved. The author's conviction of the importance of decreasing failure rate seems somewhat premature in the light of other published discussions; certainly, as is pointed out, further research is needed in this area. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure concepts in reliability theory

AUTHOR: Robert A. Kirkman, Space Technology Laboratories, Inc., Los Angeles, California

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 1-10

The material in this paper is found also in the paper covered by Abstract and Review Serial Number 1366. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number · NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1476
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the reliability of a worst case designed nonredundant circuit

AUTHOR: C. A. Combs, Jr., Computer Department, General Electric Company, Phoenix, Arizona

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 11-14

PURPOSE: To derive rigorously some general equations for the reliability of a worst case designed circuit.

ABSTRACT: A worst case designed circuit is defined and, based on observed component failure modes, a mathematical model for circuit reliability is obtained. A special case of the general model is then considered by assuming all the component failure rates to be equal. Using this simplified model it is established that a worst case designed nonredundant circuit is more reliable than the product of the reliabilities of its components. The mean time to failure (MTTF) is computed and it is shown that, for particular extreme values of the parameter p, the MTTF assumes the classical forms more frequently seen in the literature. (Author)

REVIEW: In this paper it is assumed that drift failures and catastrophic failures are independent events. From a practical point of view this is not an unreasonable assumption. However, in the third paragraph of the text it is further assumed that "... 100p% of the failures were drift failures...and 100(1-p)% were catastrophic failures..." To the unsuspecting reader this implies that drift and catastrophic failures are mutually exclusive events, contradicting the assumption of independence. This is also heavily implied at the top of the first column on page 12 in the paper. But what is really meant, judging by the mathematical development, can perhaps be seen most clearly by reasoning in terms of the events $\overline{C}_i$ that the i th component does not fail catastrophically and $\overline{D}_i$ that the i th component does not fail due to drift. These events are clearly not mutually exclusive, and if they are considered independent, then the complementary events C_i and D_i are independent. An explanation along these lines would have averted the difficulty.

Two additional points to be noted in this paper are:

1. Lemma 1 is rather obvious and scarcely warrants a formal proof.
2. The assumption that the circuit cannot fail by drift unless all components are out of tolerance is unrealistic. In a practical situation some parts may drift far enough to cause failure while others remain within tolerance. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1477
Codes 431;824;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An application of a Markovian model to the prediction of the reliability of electronic circuits

AUTHOR: M. Tainiter, Johns Hopkins University, Baltimore, Maryland (formerly with IBM Corporation, Thomas J. Watson Research Center, Yorktown Heights, New York)

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 15-25

PURPOSE: To show how a Markovian model can be used to predict the reliability of electronic circuits.

ABSTRACT: All the parameters of each component are assumed to be mutually independent. A circuit is considered to be influenced, then, by a number of independent parameters. Each parameter has values which are classified into states. There is a circuit state for each combination of parameter states. Some circuit states will be "failure" and some will be "success." This paper describes the application of the theory of continuous time Markov processes to compute the reliability of the circuits. References are given for checking on whether all the assumptions of the analysis are actually met by the parameters at all times. Three examples illustrate the use of the method.

REVIEW: The understanding of the technical portion of the paper requires some knowledge of Markov processes; in any event, the serious reader will need to have some of the references at hand. Examples of the usefulness of the method are given in Appendices II and III. In Appendix II it is shown that the true reliability problem with an emitter-follower circuit is obscured using the common Monte Carlo method, yet becomes evident when the Markovian method is used. In Appendix III the method is successfully applied to a fairly complicated circuit. While the full range of application of the Markovian method is difficult to establish, these examples do provide evidence of its usefulness. In Appendix I, which deals with the computation of the reliability of a single resistor, the agreement between the Markovian results and the empirical estimates of reliability seems none too good; some discussion of the uncertainties and statistical variations would have been helpful.

The method undoubtedly deserves further work by theoreticians. There are many theoretical problems to be solved if the range of applicability of the model is to be extended. Until that work is done, only, the rather enterprising design engineer will find much use for it; and then he must be quite careful. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1478
Codes 431;821

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimation, hypothesis testing and parameter correlation for Markov chains

AUTHOR: M. Tainiter, Johns Hopkins University, Baltimore, Maryland (formerly with IBM Corporation, Thomas J. Watson Research Center, Yorktown Heights, New York)

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 26-35

PURPOSE: To present the methods used to verify the assumptions made in an earlier report.

ABSTRACT: This paper discusses four problems in statistical inference for Markov chains. Specifically, techniques are described to do the following: (1) estimate the transition probabilities of first- and second-order stationary Markov chains; (2) test the hypothesis that a stationary Markov chain is of first order against the alternate hypothesis that the chain is of second order; and (3) test the hypothesis that a first-order Markov chain has stationary transition probabilities against the alternate hypothesis that the transition probabilities are not stationary. A technique is also developed which can be used in testing to determine whether two parameters of a single electronic component drift independently of each other.

The results of these tests are used to draw some inferences about continuous-time Markov processes. (Author in part)

REVIEW: As indicated in the PURPOSE, above, this paper is essentially a sequel to an earlier report. That report was covered by Abstract and Review Serial Number 51. This paper is a competent mathematical treatment which accomplishes its specific objectives. The assumption in the earlier report that a continuous-state Markov process can, by grouping of states, be satisfactorily regarded as a (continuous-time) Markov chain is, however, not checked by this analysis.

Some evidence of the usefulness of these statistical methods is given in the paper covered by Abstract and Review Serial Number 1477. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1479
Codes 431;872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Introduction to cyclic replacement systems

AUTHOR: B. B. Winter, Autonetics, A Division of North American Aviation, Inc., Anaheim, California

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 36-49

PURPOSE: To give a tutorial treatment of cyclic replacement systems with the use of Markov processes.

ABSTRACT: A fundamental and unified treatment of problems akin to the classical Swedish Machine Problem is presented. Section I describes the nature of the systems known as cyclic replacement systems. In Section II pertinent facts about Markov processes are gathered. In Section III, it is shown that a certain class of cyclic systems behave as homogeneous Markov processes. The special class of homogeneous Markov processes known as homogeneous birth and death processes is considered in Section IV. Results of Section IV are applied to some cyclic replacement systems in Section V. In Section VI some systems are treated which cannot be represented as birth and death processes. (Author)

REVIEW: This is a good tutorial paper, although some background in matrix notation and basic knowledge of stochastic processes will be helpful in reading it. It is a theoretical treatment (and has no immediate "practical" interest for the design engineer). Not all of the mathematics was checked, but it appears to be of high quality in general. It is a paper that will have to be studied rather than read if it is to do any good. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1480
Code 817

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Optimizing trade-offs of reliability vs weight

AUTHOR: D. P. Herron, Central Engineering Laboratories, FMC Corporation, Santa Clara, California (formerly with Advanced Technology Laboratories, A Division of American-Standard, Mountain View, California)

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 50-54

PURPOSE: To develop the necessary conditions for maximizing reliability when the equipment is subject to one or two constraints.

ABSTRACT: If reliability is a function of the weights of several items and the total weight is a system constraint, then a relationship exists for maximum reliability subject to this constraint. The method of Lagrangian multipliers is used to derive the condition $\partial R/\partial W_i$ = a constant, where R is system reliability and W_i is the weight of the i th item. If the reliability is the product of the item reliabilities R_i and if R_i is a function only of W_i, then $d(\ln R_i)/dW_i$ = a constant.

If there are two constraints the results are more complicated. They can usually be simplified by assuming a quadratic relationship between R and the W_i. The coefficients can be determined empirically for this relationship by several standard methods.

An example is given of the single-constraint application.

REVIEW: This is a straightforward paper; although the algebra was not completely checked, the results appear reasonable. The general utility of the method is subject to the restriction that the partial derivatives are known or can be determined. This could prove to be a severe limitation. The usual cautions about maxima as compared to other stationary points should be observed; e.g., the result could be a minimum. The validity of the inverse relationship--minimum weight for a given reliability was stated but not proved. Caution should be used in this regard since multivalued functions are not unknown in the real world.

This is the type of problem to which the linear programming technique should be applicable. The author, in a private communication, has indicated that dynamic programming procedures are applicable when discontinuous functions are involved.

A paper which treats this topic in a rather different way (by the use of redundancy vs. constraints and reliability) was covered by Abstract and Review Serial Number 1267. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1481
Codes 821;831;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Two algorithms for computing reliability

AUTHOR: Richard C. Dubes, Electrical Engineering Department, Michigan State University, East Lansing, Michigan

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 55-63

PURPOSE: To demonstrate two algorithms for computing the reliability of some special systems.

ABSTRACT: This paper develops two algorithms for finding the time-dependent reliability of any active-redundant system in terms of component failure probabilities. The first algorithm is used when each component can fail in only one mode. A procedure, based on the Quine-McCluskey technique from switching circuit theory, is stated in conjunction with this algorithm which permits rapid simplification of the reliability expression. Two failure modes are permitted in the second algorithm. The relation between the expressions resulting from the algorithms and lifetime random variables is given so that the algorithms do not depend on specific component failure distributions.

The analysis is restricted to systems with the following properties.

1. Failure probabilities of all components are independent of the state of any other components.
2. The system contains neither standby nor majority redundancy.
3. Each component is either failed open, failed short, or not failed. All failures are catastrophic. (Author in part)

REVIEW: The methods presented here are quite general for systems which satisfy the assumptions. The utility of the algorithms will depend on familiarity with them, which in turn depends on how often they are used. The explanation of the procedure in the text will require a fair amount of study for those not already familiar with the notation.

(Some of the introductory material tends to be confusing unless read very carefully. In one example, it is stated that if the overall failure behavior is Poisson, that for opens and shorts is also Poisson. This is obviously not true and the correct equations--not words--are given.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1482
Codes 831;838;872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Approximation formulas for reliability with repair

AUTHOR: Malcolm A. McGregor, Westinghouse Defense Center, Baltimore, Maryland

SOURCE: IEEE Transactions on Reliability, vol. R-12, December, 1963, pp. 64-92 (see also "Correction", IEEE Transactions on Reliability, vol. R-13, March, 1964, p. 48)

PURPOSE: To develop approximation formulas for the calculation of system reliability with repair.

ABSTRACT: A system consists of n identical parallel subsystems, each having an exponential distribution of times to failure and an exponential distribution of times to repair. The system reliability with repair is the probability of no more than q out of n subsystems being simultaneously in a failed state during time t. Under conditions frequently met in practice, system reliability with repair R(t) can be approximated by: $R(t) \cong \exp[-t/T_m]$, where T_m is the mean time for the system to pass for the first time from zero to (q + 1) simultaneous subsystem failures. Exact and approximate methods of calculating T_m are developed. A detailed error analysis is presented showing the limitations of using T_m to calculate system reliability with repair. The reliability-with-repair approximate formulas developed in this paper simplify the calculations of system reliability with repair. The error curves are used to quickly determine the magnitude of the approximation error as a function of operation time t, subsystem failure rate λ, subsystem repair rate u, total number of subsystems n, and the number of permissible simultaneous subsystem failures q. In all cases, using the approximation formulas results in a pessimistic value of system reliability with repair. The error curves show that values of $u \geq 10n\lambda$ for single repair capability, or $u \geq 5n\lambda$ for multiple repair capability result in negligible approximation errors in many practical cases, especially when $q \geq 3$. (Error curves for q = 4 and q = 5 are available upon request.) Values of $u < 10n\lambda$ for single repair or $u < 5n\lambda$ for multiple repair can be used, provided the increase in approximation error can be tolerated. (Author)

REVIEW: This is a detailed mathematical paper. The reviewer has not checked all of the algebra, but anyone wishing to use the results will find it desirable to follow the derivations sufficiently closely to appreciate their implications and hence their applicability. The attention given to the assessment of approximation errors is commendable. For those who may desire more background details, ten pertinent references are cited. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1483 -1
Codes 815;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Characterization of transistors--a status report

AUTHOR: C. D. Simmons, Philco Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 140-161

PURPOSE: To discuss the various philosophies used for the specification of transistors and to report on the accuracy which can be achieved using the most modern specification techniques.

ABSTRACT: Adequate specification of transistor characteristics is important for high-reliability transistor performance; but only when a transistor is manufactured exclusively for a particular use can its operating conditions be completely determined in advance and thereby be accurately and adequately covered in specifications. For the more common "standard system" applications the problem of specification is one of defining the device characteristics accurately enough so that the user can predict the performance and reliability in his own particular application. Various types of specifications are commonly used to furnish this information:

1. Static characteristics (h_{FE}, I_{CBO}, I_{EBO}, etc.)
2. Matrix parameters (h-parameters, y-parameters, etc.)
3. Equivalent circuits (hybrid-pi, many others)
4. Figures of merit (f_{max}, f_T, $r_b'C_c$)

Less well known but better suited for switching applications is the specification of charge parameters based on a charge control model of the transistor. Charges are more difficult to measure than either currents or voltages, however. Therefore this method is not completely satisfactory. A superior method is one which combines both simple models, such as the charge control model or any of various transistor equivalent circuits, and sample measurements in the intended operating range. This method of presenting specifications is called the pseudo-parametric method and is shown to be advantageous in applications using switching transistors or tuned RF amplifier transistors. For other transistor applications other specifications are preferable. Methods for specifying (1) the end of transistor life and (2) various maximum ratings are unsettled.

REVIEW: This paper summarizes the various methods of writing transistor specifications and recognizes the dilemma facing the transistor manufacturer who is attempting to describe his product as a general-purpose component useful over a wide spectrum of applications. No clear solution to this problem emerges and the impression is that the best method of specifying transistor performance

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

inevitably depends upon its application.

The descriptions of the "transistor specification philosophies" assume that the reader is already generally familiar with the area and the various philosophies are classified and contrasted rather than explained in detail. The discussion appears complete in breadth.

Just what the author meant by the stated purpose "to report on the accuracy which can be achieved using the most modern specification techniques" is not clear. Neither is it clear what he regards as "the most modern specification techniques". The paper discusses five or six methods, all of which seem appropriate under some circumstances. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1484
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor equivalent circuits and preferred design parameters

AUTHOR: William Kronlage, Texas Instruments, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 181-189

PURPOSE: To discuss the equivalent circuits for alloy and diffused transistors.

ABSTRACT: While diffusion and evaporation technologies in transistor fabrication have provided devices of greatly improved performance, the equivalent circuits and physical models necessary to describe their characteristics in the active and saturation regions have become more complex.

This paper discusses equivalent circuits applicable, in the active region, to alloy and diffused transistors and contrasts the behavior of the two classes in saturation. The preferred design parameters for data sheet specifications are given and are related to transistor performance in several typical applications.

A number of easily measurable parameters form the basis for characterizing transistors. Good control of these parameters best assures the constant quality of the devices. While functional tests are generally avoided (because they are costly and do not provide the most general type of information), they are sometimes used, especially in describing the transient performance of switching transistors. (Author)

REVIEW: This is not an elementary discussion--some knowledge of transistor equivalent circuits is necessary for understanding it. In reading this paper, it should be remembered that it was originally given in 1961. The charge control model of transistor transient performance is not mentioned. The article does not deal with reliability, per se. (See also the paper covered by Abstract and Review Serial Number 1483.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1485 -1
Codes 815;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductor device ratings--their determination and use in reliable system design

AUTHOR: M. L. Embree, Bell Telephone Laboratories, Inc.

SOURCE: <u>Semiconductor Reliability Volume 2</u>, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 190-210

PURPOSE: To promote a common understanding of device ratings and to recommend certain standards as worthwhile additions to existing military specifications on ratings.

ABSTRACT: The use of three types of conditional ratings, "Absolute Maximum," "Recommended Maximum," and "Conservative Design Maximums," is recommended in order to achieve an adequate description of semiconductor devices for the design of complex, highly reliable, electronic equipment.

Ratings can be conveniently divided into two classes, "threshold" and "time dependent." Threshold ratings can be determined by extrapolating the failure distribution as a function of stress to a "standard failure percentile." Time dependent ratings can be determined by extrapolating the high stress aging acceleration characteristic for a "standard failure percentile" to a "standard period of time."

The adoption of 1 percent for the "standard failure percentile" and 1000 hours for the "standard period of time" is recommended. This standardization can be achieved by a simple addition to the definition of ratings in MIL-S-19500.

Lot-by-lot or periodic acceptance inspection tests, with LTPD sampling requirements of from 5 to 10 percent, should be required to assure device conformance to the specified ratings. In the final analysis, the results of these tests will determine the validity of the ratings.

The equipment designer uses maximum ratings as a basis for determination of component failure probabilities. A complete system reliability analysis involves a summation of all individual component failure probabilities. A reiterative analysis involving device choices from a rating and failure characteristic standpoint and variation of designable stress conditions may be used to achieve satisfactory device reliability to meet system objectives.

The above conclusions are supported by ample test data on the 1N669 (27-volt voltage regulator diode), the 1N673 (silicon rectifier diode) and the 2N559 (diffused germanium transistor). (Author in part)

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: The principal emphasis in this paper is on the second of its two stated purposes. The problem of conveying accurately as much information as possible on a device from the manufacturer to the user is clearly stated. The author's contribution is the recommendation that, once having decided to measure a given parameter, the information should be presented according to the 1%, 1000 hours standards (see ABSTRACT). These standards seem worthwhile and economical. Military procurement personnel are probably in the best position to initiate their implementation. The specific numbers chosen as standards are less important than the fact that standards should exist such that the ratings in specification sheets mean the same everywhere and to everybody, manufacturer or purchaser. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1486
Code 775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determining seal quality as a key to semiconductor device reliability

AUTHOR: W. E. Dunkel, International Business Machines Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 211-228

PURPOSE: To discuss methods for evaluating the hermetic seals of semiconductor encapsulations.

ABSTRACT: Conventional tracer gas bombing methods (helium, krypton 85), used to spot "leakers", generally yield little correlation between the measured leak rates and the degradation of the encapsulated semiconductor in subsequent life tests. From the physics of viscous and molecular flow anticipated to apply to the leaks encountered in a standard encapsulation, it is shown that variations in the effective volume inside a package and in the time between bombing and counting should and do lead to errors in the measured leak rate. Other methods such as flow-through type measurements and penetrating dye can be employed to obtain more accurate information on leaks.

REVIEW: The editing on this paper was quite inadequate. Omission of the fraction signs in Equation 11, the switch of constants between Equations (3) and (4) and (12) and (13), and the absence of a list of references in spite of numbers in parentheses scattered throughout the paper are not major shortcomings, but the incomprehensible, unclear statements which appear all too frequently seriously detract from the impact of this paper. Too much of the reader's time is spent in guessing at what is meant instead of thinking about the problem discussed. This is unfortunate since the subject is important and not adequately treated in the literature at present. Examples of unclear statements in the first few pages are (1) "... the mean free path of air at a temperature of 25C and pressure of 1 micron is approximately 5 cm. as compared with 2 x 10^{-6} cm(0.02 micron)," (2) "... with the values caused by the measuring system used combined to C, Equation 1 changes to ...," and (3) "Let us now critically examine the bombing methods with the assistance of Equation 11 to be valid."

An important observation which does emerge is that leaks in transistor headers occur primarily at the seal between the leads and the header rather than at the weld between the cap and the header. The author suspects that the source of these leaks is at the Kovar-iron oxide interface rather than at the iron oxide-glass interface. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1487
Code 770

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Standardization of semiconductor life test circuits

AUTHOR: Norman S. Ince, Texas Instruments, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 229-235

PURPOSE: To discuss several of the semiconductor life test circuits in use and to outline the problems associated with obtaining and presenting accurate reliability information.

ABSTRACT: The increasing demands for qualification of devices to particular levels of reliability and for lot acceptance tests to prove continued repeatability of this quality can be met only with devices of sufficient quality. However, to prove reliability of the device rather than the test circuit and/or life test conditions, much thought should go into consideration of a standard set of circuits, conditions, etc. A few items for writers of such specifications to consider are:

1. Conditions of storage or operation should be strict, but realistic.
2. A specific circuit and voltage should be included in each military specification and should be similar between families that are closely related.
3. Device dissipation should be held at the desired rating. Instability, due to heating, etc., should not cause the dissipation rating to exceed the maximum rating.
4. The device should be protected, if at all possible, from self-destruction for the performance of failure analysis.
5. Only one maximum rating should be realized at a time in such tests or in actual application.
6. Rate of air flow must be considered on all devices that are not operated on heat sinks.
7. Realistic definition of failure.
8. Realistic selection of pertinent parameters.

This paper discusses several of the semiconductor life test circuits presently utilized and outlines the problems associated with obtaining accurate reliability information and presenting reliability data on parts tested in the circuits. A brief discussion of the need for a standardized system of life tests is included. (Author in part)

REVIEW: This paper gives the impression of a hurried and superficial piece of work, typified by the above ABSTRACT. None of the circuits discussed are considered in any detail, and any recommendations for standardization are implicit rather than explicit. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1488
Code 823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life testing models

AUTHOR: Chester H. McCall, Jr., Vice President, Booz-Allen Applied Research Inc., Los Angeles, California

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 20-25

PURPOSE: To give a tutorial view of some common life-testing models.

ABSTRACT: The following six models are mentioned: exponential, Gaussian, log Gaussian, Weibull, gamma, and L-J. The density function of the L-J distribution is

$$[X\Gamma(\gamma)]^{-1}\ \beta(\alpha X^{\beta})^{\gamma}\ \exp\ [-\alpha X^{\beta}],$$

where α, β, and γ are parameters of the distribution and X is the random variable. By suitably assigning values to α, β, and γ, the L-J distribution can be made into the Weibull, gamma, "bath tub," etc. A test may be made for the purpose of estimating the parameters of a particular model or for checking the hypothesis of the adequacy of a model. Almost any data can be fitted after-the-fact if there are enough parameters at one's disposal--but little is accomplished. Engineers and statisticians need to work together to derive adequate mathematical models. A few references are given.

REVIEW: This is a short survey of the distributions mentioned; it tells little about them except the probability density functions. The two philosophical points (mentioned in the ABSTRACT above) are both important. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1489
Codes 811;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Organization and operation of a failure analysis laboratory

AUTHOR: Orland F. Bergere, Quality Assurance Department, UNIVAC Division of Sperry Rand Corporation

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 26-30

PURPOSE: To present the failure analysis system of the UNIVAC Division.

ABSTRACT: Failure analysis, so popular in the military equipment field, has been adapted to meet the needs of the UNIVAC Division. The system includes the following three parts:

1. Failure/malfunction reporting,
2. Failure analysis, and
3. Corrective action follow-up.

Each of these is discussed briefly.

REVIEW: This is a rather conventional program for failure analysis and not controversial except for the random sampling of the failures. The procedure is not detailed at all, which is a disadvantage since many people seem to feel that all items should be processed. However, time and cost may well limit the size of the project, in which case the sampling, properly done, may be the best approach. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1490
Codes 613;814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A preliminary cost/reliability model for a multi-satellite system

AUTHOR: Paul Gottfried, Booz-Allen Applied Research Inc., Bethesda, Maryland

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 31-43

PURPOSE: To derive a cost/reliability model such that the economic consequences of decisions are relatively independent of the exact payoff function.

ABSTRACT: The annual cost of a long-term satellite system is a function of the ratio of the initial cost C to the mean life M, i.e., to C/M. It is possible to hypothesize a ΔC vs. ΔM model. For $0 \leq \Delta C \leq k$, $\Delta M = 0$ (where k represents some minimum start-up expense). For $k < \Delta C \leq m$, assume the relationship is linear (up to some incremental expenditure m) and that it corresponds to the optimum technique. For $\Delta C > m$, assume that $M = M'(\Delta C/m)^d$, where d is a positive number less than 1. It is easy to put some bounds on d due to the facts that the slope must be less than that of the optimum linear phase and that a point of diminishing returns will be reached. An example shows that, within these bounds, a deviation in the true value of d from the estimated value does not entail large economic risk if the decision (economic commitment) is optimal for the estimated value. The final decision is, of course, tempered by other factors.

REVIEW: This paper fulfills the purpose of presenting a model which may be reasonably adequate for predicting cost in terms of mean life. It is, of course, a simple model and factors such as future benefits from the investment are not considered. Just how useful it will be in practice is difficult to say; while the decisions may be relatively independent of d, they do depend on the form of the model. One point to beware of in the use of any model in this circumstance is the forgetting of how arbitrary the model is in the first place and the consequent putting of the decisions on an unbreakable pedestal. ##

Serial Number 1491
Codes 700;800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The relay communications satellite, fact vs. theory

AUTHORS: H. L. Wuerffel and R. P. Dunphy, RCA, Astro-Electronics Division, Princeton, New Jersey

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 54-72

PURPOSE: To describe the Relay I satellite, its mission and accomplishments.

ABSTRACT: The Relay Project is a NASA/Goddard-sponsored experiment and has three basic objectives: (1) to determine the propagation characteristics of wide-band transmission between remotely located stations by means of a low altitude active repeater, (2) to obtain information on particle radiation in space and its effect on solar cells and semiconductors, and (3) to arrive at a better understanding of the cost aspects of such a communications system. Since the environments in which a communications satellite system must operate were not fully understood, a number of radiation experiments were incorporated into the Relay Satellite. The reliability goals were 93% probability of success for one month and a mean time to total failure of one year.

The subsystems are: Wideband communications (735 electronic and electromechanical parts), Radiation experiments (59), Tracking, telemetry, and command (6348), Power supply (228), Thermal control (0), Attitude control (68), Structure (0). It was necessary to use redundancy to achieve the reliability goals. Design reviews and circuit simplification were important phases. The methods of construction and testing are explained. Parts were extensively preconditioned before installation. Very tight controls were exerted at all points to be sure that the model flown was exactly the same as that which had been successfully tested. The performance in orbit has generally been successful, although intermittent difficulties were experienced. Relay I has met all of its experimental objectives. The experimental results obtained from in-orbit operation indicate close correlation to prelaunch measurement, and the spacecraft has contributed appreciably to man's knowledge about the space surrounding him. (Authors in part)

REVIEW: This is a good summary of the problems encountered in creating the Relay satellites and the methods used to solve them. (A minor omission is the lack of crediting a little bit of luck -- which is necessary to win any statistical contest.) A more complete discussion of the technical details will be found in [1].

REFERENCE: [1] J. D. Keisling, "The NASA Relay I experimental communication satellite," RCA Review, Vol. 25, June, 1964, pp. 232-261 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1492
Code 816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable parts procurement for electronic equipments

AUTHOR: P. U. Aasgaard, Canadian Marconi Company, Montreal, Canada

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 73-80

PURPOSE: To discuss the problems associated with the procurement of good parts for projects of intermediate size.

ABSTRACT: Quality control has developed through the following three phases: the skilled craftsman, inspection, control. Reliability is now in the middle phase; it needs to progress to the third. Projects of moderate size cannot afford the vast complex formal approach to reliability, and yet they are too large for one man to shepherd through. There are three main problems: statistical, design, and communication. In using statistics we should realize that there are no "chance" failures, that all failures have specific causes. Statistics measures our ignorance here. Tests to destruction are more informative than tests at nominal conditions. The designer usually has to depend on others for the details of part-selection and purchasing. It is in this area that communications becomes a real problem. Ideally, the designer should talk with technical people in the supplier's plant; then the designer's purchasing and the vendor's sales departments should handle the details of the transaction. Both sets should, of course, keep each other informed. A specification should be complete enough to get the desired parts--assuming capable suppliers, but not so complicated that much of it is misunderstood or ignored.

REVIEW: The paper is rather short and treats isolated portions of the general problem. The discussion of the statistical aspects makes some very good points; the part on communications addresses itself largely to the problem of how to negotiate for reliable parts. The topics actually covered are handled reasonably well, and the paper is worthwhile reading for those concerned with the problem of procuring reliable components. However, some of the assertions made relate to rather controversial points. For example, many will argue that reliability is more than a quality characteristic. Also, while the argument for leaving some requirements in specifications unstated is convincing, there remains the problem of where, in specific situations, one would draw the line on the level of detail. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1493
Codes 510;820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Confidence limits and their significance in reliability studies

AUTHOR: Edward C. Longhurst, Product Design Assurance, RCA Victor Company, Ltd., Montreal, Quebec

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 81-90

PURPOSE: To call attention to certain facts which are easily overlooked.

ABSTRACT: The tremendous volume of background statistical theory published in the field of reliability assessment and prediction has not concerned itself in sufficient proportion with the general situation--that is, where the failure rate increases progressively with time. This 'wear' or degradation effect in operating equipment makes its appearance quite early in the useful life period, and must be held at bay by the judicious replacement of unfailed early wearout parts to ensure acceptable equipment longevity. The majority of such parts are electro-mechanical or mechanical in nature, and it is obvious that they will constitute a serious problem in the reconciliation of field reliability reports with a priori analytical assessments, as well as in the field of logistics and spares provisioning.

This paper offers simple and effective applications of mathematical treatments to these situations, but it recognizes that reasonable statements of confidence must be confined to those failure effects which are distributed in a random fashion, where failure effects are additive, and where quantities of units may be multiplied by the appropriate values of operating time to furnish the operative number of 'unit-hours'. None of these conveniences can be employed where failure rates are increasing with time. It is essential, therefore, that statistical investigations and theoretical treatments of the most advanced nature be brought to bear in this field. (Author)

REVIEW: It is not very clear just what problems the author is really attacking. There is no theoretical or practical problem with confidence limits (other than the general ones which arise when the users do not understand the concepts) for either the exponential or Gaussian distributions. The author's inference that the exponential is random and that the Gaussian is not is quite erroneous--they are both distributions of a random variable. The discussion of the Gaussian distribution contains incorrect statements (e.g. the curve in Figure 1 is the probability density function, not the cumulative function).

In short, this paper is of little use as a reference or source of information. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1494
Codes 720;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The NASA soldering program

AUHTOR: Bertram E. Monty, Quality Assurance Field Representative, National Aeronautics and Space Administration, Cambridge, Massachusetts

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 91-95

PURPOSE: To discuss the NASA hand soldering program and the associated specifications.

ABSTRACT: The solder connection is still common enough that all NASA programs are at the mercy of its reliability. This importance of soldering has led to NASA documents MSFC-PROC-158B, "Soldering of Electrical Connections (High Reliability)" and NPC-200-4, "Quality Requirements for Hand Soldering of Electrical Connections." These documents require that all personnel either performing or inspecting soldering operations be certified and be periodically examined. Some other NASA requirements for performing and inspecting hand soldering are discussed, including soldering standards.

REVIEW: The NASA requirements associated with hand soldering that are presented in this paper are in some instances more strict than typical industrial practices, e.g. complete operator and inspector certification. Hence this paper will be of interest to those doing business with NASA. The utilization of quality specifications with specific requirements such as these will minimize misunderstandings between governmental agencies and contractors which have occurred under the more general quality and reliability specification.

The brief example on soldering error probability includes the Government Inspection Agency and NASA Inspector on the basis of 100% inspection to achieve the cited overall process error. Typically these inspections are performed on a low sampling basis, and the general applicability of this example is questionable. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1495
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: NASA's reliability requirements

AUTHOR: John E. Condon, Office of Reliability and Quality Assurance, NASA Headquarters, Washington, D. C.

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 96-101

PURPOSE: To provide a discussion of the new NASA reliability specification which is to have general application.

ABSTRACT: A new NASA specification, NPC 250-1, "Reliability Program Provisions for Space System Contractors" was issued recently. It is aimed at providing guidelines for all NASA programs in designing reliability into space systems and preventing reliability degradation. Those aspects of a reliability program which are peculiar to a particular system will be detailed in the specific reliability program plan for the system. NASA's right to employ independent reliability assessment contractors is reserved in this specification. The principal system reliability program elements of NPC 250-1 are program management, reliability engineering, and testing and reliability evaluation. Each of these is discussed.

REVIEW: This specification reflects the accumulated experience in reliability management and engineering within the government contracting environment. It will assist in bringing further order, standardization, and efficiency into this area, but accomplishment will still be limited by the collective knowledge and intentions of the contractor and the NASA procuring agency. The most interesting element of NPC 250-1 is the relatively new concept of an integrated test program which is to have an explicit relationship to reliability assessment. Any implementation problems which may occur are likely to be in this area. This paper will be of particular interest to contractors doing business with NASA. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1496
Codes 820;830;840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The role of stress analysis in reliability prediction

AUTHOR: Leonard C. Thomas, Product Design Assurance, RCA Victor Company, Ltd., Montreal, Quebec

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 102-106

PURPOSE: To reiterate some of the assumptions, applications, advantages, and pitfalls of stress analysis.

ABSTRACT: Stress analysis for electronic equipment is the means of predicting individual part failure rates taking into account electrical stress and temperature. The failures are assumed to follow a Poisson process which implies several limitations. These better estimates of failure rates (obtained through stress analysis) are useful in many ways.

REVIEW: In general, the points made in the paper about the need for and the benefits of failure-rate prediction based on an accurate knowledge of "stresses" are good. The use of the concept of stress analysis to include the failure rate determination -- rather than limiting it to the analysis of stress at any particular place -- while not uncommon, tends to be confusing. The claim that stress analysis is best done by someone other than the designer is controversial -- many feel that the ideal situation is to have it done by the designer and merely checked during a design review. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1497
Code 872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Problem of securing reliable operation of a control installation

AUTHORS: A. V. Zakharov and A. V. Mayorov (Moscow)

SOURCE: Izvestiya Akademii Nauk SSSR, Otn, Energetika i Avtomatika, Issue Nr. 2, 1960, pp. 205-207, Translation prepared by Translation Services Branch, Foreign Technology Division, WP-AFB, Ohio, FTD-TT-61-141/1+2, 1 November, 1961 (DDC AD No. 267717)

PURPOSE: To propose a procedure for determining an adequate preventive maintenance policy.

ABSTRACT: Preventive maintenance can be a valuable means of increasing system reliability. However, it is desirable to schedule maintenance in such a manner that maximum reliability gain is achieved with minimum time devoted to maintenance. One method of accomplishing this consists of the following steps:

1. Divide the interval of expected operation into several sub-intervals.
2. Calculate the mathematical expectation of the time to failure in these sub-intervals, using data from similar installations.
3. Use the results of Step 2 to estimate the amount and frequency of preventive maintenance work which is adequate to maintain trouble-free operation.

Successive inspections should include all the steps of previous inspections. Implementation of this procedure should insure adequate preventive maintenance. However, it is not a necessary criterion; i.e., the amount of time allowed for maintenance may be in excess of that which is actually needed.

REVIEW: This paper is a rough-draft translation and reads accordingly. The ideas behind the original work may have been good, but they have not been expressed clearly in the translation. Of course this could be due to excessive brevity or lack of clarity in the original paper. In particular, it is not clear just how Step 3 (see ABSTRACT) is carried out, yet this is the key part of the procedure. In any event, no proof of the adequacy of the proposed preventive maintenance procedure is offered. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1498
Codes 821;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the reliability of an amplifier with automatic amplifier control

AUTHOR: B. R. Levin (Moscow)

SOURCE: Izvestiya Akademii Nauk SSSR, Otn, Energetika i Avtomatika, Issue Nr. 2, 1960, pp. 208-209, Translation prepared by Translation Services Branch, Foreign Technology Division, WP-AFB, Ohio, FTD-TT-61-141/1+2, 1 November, 1961 (DDC AD No. 267717)

PURPOSE: To present formulas for evaluating the effect of automatic amplification control on the increase of amplifier reliability.

ABSTRACT: Feedback may be used to improve the reliability of certain systems despite the fact that it requires an increase in the number of unreliable elements. Amplifier reliability is a case in point. The reliability of an amplifier with n identical stages, each having amplification k, without automatic amplification control is given approximately by

$$p = p_o^n \{F [\frac{\ln k(1-\delta_1) - na_1}{\sigma_1 n^{1/2}}] - F [\frac{\ln k(1+\delta_2) - na_1}{\sigma_1 n^{1/2}}]\}, \quad (1)$$

where F(x) represents the cumulative function of the standard normal variable x, p_o is the probability that a stage will not fail catastrophically, δ_1 and δ_2 are the tolerance field limits for a stage, σ_1 is the standard deviation of the gain distribution for a stage, and a_1 is the average logarithm of the gain per stage. If automatic amplification control is used, (1) is replaced by

$$p^* = p_o^n p_{oc} \{ 1 - F [\frac{\ln k\delta_1 - na_1}{\sigma_1 n^{1/2}}] \} , \quad (2)$$

which holds approximately for large n, p_{oc} being the reliability of the feedback apparatus. A numerical example is given to illustrate the favorable effect of feedback on the reliability of the amplifier.

REVIEW: This is a rough draft translation, and considerable ingenuity is needed by the reader in extracting worthwhile information from it. The conclusions reached must be regarded with some doubt, due to the difficulty in following the development. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1499
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Achieving more accurate judgements of the reliability of germanium transistors

AUTHORS: Arnold J. Borofsky and Jayne Partridge, Sylvania Electric Products, Inc., Woburn, Massachusetts

SOURCE: 34 pp., prepared for presentation at the "Symposium on Cleaning and Materials Processing for Electronics and Space Apparatus," American Society for Testing Materials, Fourth Pacific Area National Meeting, October 3, 1962, Los Angeles, California (NASA accession number N62-17697)

PURPOSE: To present a philosophy for achieving a more accurate estimate of device reliability and to illustrate the use and benefits resulting from such an approach.

ABSTRACT: Assurance that failures occurring on stress tests are due to device faults and are not externally caused requires a comprehensive analysis of degraded devices and a knowledge of the variability of the conditions under which the devices have been stressed and measured. Changes of the surface-dependent parameters of germanium transistors may reflect relatively permanent changes in the conditions at the junction surface, short-term changes, bulk or contact resistance variations, or combinations of these. Analysis of the changes in device properties which arise from each of these causes suggests the techniques to differentiate between device faults and externally caused failures.

The results of this study show that meaningful reliability testing of germanium devices depends on a thorough knowledge of: (1) the degree and variation of the precision of the stress and measurement equipment, (2) an understanding of the temporary and permanent changes in device parameters, and (3) accurately defined failure mechanisms.

Suggested methods to insure these goals are: (a) utilization of reasonable and consistent time following removal from stress for the measurement of device parameters, (b) measurement of the parameters in the order of increasing reverse bias, (c) application of control chart statistics to parameter measuring equipment, (d) continuous monitoring of stress conditions, and (e) utilization of a comprehensive system for identifying failure modes, underlying mechanisms and contributing factors. (Authors in part)

REVIEW: This report presents a philosophical discussion of the reliability testing of germanium transistors. The persentation is thorough and is complemented by a number of graphs, charts, and photographs. Twelve references to pertinent literature are cited. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1500
Codes 412;421;824;
831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimating missile reliability

AUTHORS: S. Blumenthal and J. Denton

SOURCE: Technical Report No. 81, 17 pp., October, 1962, prepared under Contract Nonr-225(52)(NR-342-022) for Office of Naval Research by Applied Mathematics and Statistics Laboratories, Stanford University, Stanford, California (DDC AD No. 291603)

PURPOSE: To solve a problem in the estimation of missile reliability.

ABSTRACT: Consider a circle of radius ρ surrounding a target T such that if a missile detonates within the circle, T is destroyed; otherwise it is undamaged. Each missile has reliability R defined as the probability that the missile, when aimed at the target, detonates within the circle of radius ρ. It is shown that the problem of estimating the number of missiles to be expended on the target T to ensure its destruction with given probability, while maximizing the number of targets attacked, reduces to the problem of finding an estimator $\hat{R}$ which underestimates R with predetermined probability. It is assumed that T lies at the origin of a Cartesian coordinate system in which (x_i, y_i), i = 1,..., n denote the points of impact of n missiles. X and Y are assumed to be independently normally distributed with zero means unknown variances σ_1^2 and σ_2^2. Then $R = P(X^2 + Y^2 \leq \rho^2)$. Several methods for obtaining confidence intervals for R are considered. The first of these treats the case in which $\sigma_2^2 = K\sigma_1^2$, the second involves the introduction of a random variable which takes the value 1 or 0 depending on whether the missile detonates within or outside the circle of radius ρ. Two large-sample procedures are given. The case of non-zero covariances has not yet been successfully treated. Some practical ramifications of the problem are discussed.

REVIEW: This is a mathematical paper in which a specific problem is formulated and solved. It is clearly and cogently written, and the procedures used are adequately referenced. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1501
Codes 775;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Spray-on Freon pinpoints failure at low temperatures

AUTHOR: (Value Improvement Program item; credit to: Wendell L. Oliver, Engineering Quality Control Coordinator, Collins Radio Company, Cedar Rapids, Iowa)

SOURCE: Electronic Evaluation & Procurement, vol. 4, April, 1964, p. 29

PURPOSE: To point out that spray-on Freon can show up low temperature failures easily.

COMPLETE ITEM: While running environmental tests on engineering equipment, it is at times necessary to isolate a component which is failing at extreme low temperatures (cold test). Many times this was only possible by dropping the temperature of the complete system. This process is lengthy and costly, and usually repetitious. It was suggested to the laboratory personnel that Freon (spray can) be applied to individual components to eliminate this costly process. It is now possible to quickly determine which component is failing.

REVIEW: Techniques such as this can have an important good effect on engineering for reliability. Their invention should be encouraged. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1502
Code 711

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effect of cathodic charging and cadmium plating on the fatigue behavior of high-strength steels

AUTHOR: Walter Beck, Aeronautical Materials Laboratory, Naval Air Engineering Center, Philadelphia, Pennsylvania

SOURCE: Electrochemical Technology, vol. 2, pp. 74-78, March-April, 1964

PURPOSE: To describe the effects of various plating techniques on the fatigue of high-strength steel and to interpret the results.

ABSTRACT: The fatigue limits of notched specimens of ultra-high-strength steels plated with cadmium from the cyanide bath are significantly reduced.

This phenomenon has been related to the embrittling effect of hydrogen migrating into steel during plating from the cyanide bath.

Should the design of high-strength steel parts subjected to dynamic loading require the presence of high-stress concentrations, it is suggested that the plating of cadmium from the cyanide bath be replaced by vapor deposition. (Author)

REVIEW: While the discussion of the basis for the phenomenon may be of little interest to designers, the reduction of fatigue strength shown here is of considerable importance. It illustrates the general point that designers should be familiar with many facets of the behavior of materials after they have been processed. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1503
Codes 711;713

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Predicting the fatigue life of structures for random and sinusoidal vibrations.

AUTHOR: Joseph J. Frank, Astro-Electronics Division, Radio Corporation of America, Princeton, New Jersey

SOURCE: Machine Design, vol. 36, June 18, 1964, pp. 203-206

PURPOSE: To show how to make some calculations regarding fatigue damage.

ABSTRACT: Consideration of failure by fatigue is especially important in light-weight high-strength structures. A method is presented for determining fatigue life or allowable fatigue stress when the part is excited by vibration through its resonant frequency. Two excitations are considered: (1) a continuous spectrum of accelerations having a Gaussian distribution--constant-power spectral density, and (2) swept sinusoidal frequency. In addition, a general expression for the fatigue damage is presented for the sinusoidal excitation.

Miner's hypothesis of linear cumulative fatigue damage is used and a particular form of the S/N fatigue curve is assumed.

REVIEW: The article is good in that it clearly lists the assumptions made in the derivation of results. Thus anyone with enough experience can apply these results. This is not likely to be easy for a novice (in fatigue) to do properly. The assumptions of Miner's law and the fatigue curve shape are rather arbitrary and certainly are far from being universally accepted. (The title is somewhat misleading since the structure itself is assumed to be vibrating at its resonant frequency in the case of white noise accelerations.)

No mention is made of the variability in materials properties from specimen to specimen. Presumably the paper deals with the median fatigue curve--the most common one--although others could be used equally well. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1504
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Diode logic: how important are component tolerances?

AUTHOR: J. G. Curtis, Corning Glass Works, Bradford, Pennsylvania

SOURCE: Electronic Design, vol. 12, June 22, 1964, pp. 60-65

PURPOSE: To show that tight-tolerance resistors are better than loose-tolerance ones.

ABSTRACT: Analysis is made of the ON and OFF conditions for a particular diode AND gate. The final equations are designed to maximize the fan-out. It is shown by worst-case analysis that tight-tolerance resistors allow a larger fan-out than do loose-tolerance ones. It can also be shown that circuits designed with 5% resistors use 30% fewer resistors than those designed with 15% resistors.

REVEIW: There is little doubt in anyone's mind these days that a circuit with tight-tolerance components can be more "efficient" than a circuit with loose tolerances. The problem arises in the engineering choices which are not discussed in detail in the paper--although mentioned in the subtitle. The biggest problem, other than initial cost of the system, is whether or not the particular resistors chosen will, in fact, conform to the tighter tolerances for the desired period of time. This problem is also not mentioned in the paper.

(The title and subtitle are somewhat misleading--components are not discussed in general; only resistors are mentioned. Also the economy problem is not mentioned; it is only implied by the results.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1505
Codes 720;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Advantages of crimped connections

AUTHOR: Maurus Logan, Manager of Engineering R & D, The Thomas & Betts Company, Elizabeth, New Jersey

SOURCE: Computer Design, vol. 3, February, 1964, pp. 10-11

PURPOSE: To describe some typical examples of mechanical connections made without the use of solder.

ABSTRACT: Significant innovations have occurred within the past few years in the use of non-soldered connectors. This has resulted in the use of more pressure connectors. The trend is a result of the need for reliability: it has been shown that the reliability of a connection is a direct function of the number of variables involved in making the connection, particularly the human variables. Solderless connections without exception reduce the number of process variables.

Much work has been done to improve the reliability of entire electronic systems but this can easily be jeopardized by lack of attention to connections. In any circuit, the number of connections exceeds the number of other components by a factor of four or more. Failure of any one of these connections can render the system inoperative or cause improper functioning.

Increased reliability is usually associated with increased cost, but solderless connectors often give increased reliability at lower total installed cost.

REVIEW: This is a "popular science" type discussion of the advantages of crimped connectors. There are three illustrations. Other types of connections--welded and soldered, for example--have their good points also. A more accurate statement about the influence of variety on reliability would be: "other things being equal, the reliability is a function of the number of variables..." The qualification is essential, yet it is often omitted.

Some papers on welded and soldered connections and their reliability have been covered by Abstracts and Reviews Serial Numbers 278, 315, 365, 522, 724, 864, 942, 987, 988, 1144, 1178, 1263, 1308, 1352, and 1353. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Thermodynamics of failure and aging

AUTHOR: Martin Ruderfer, Dimensions, Inc., Hempstead, L. I., New York

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 361-374 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To present a general theory of aging applicable to any physical structure.

ABSTRACT: Consider a modified Carnot engine in which a fraction of the output energy is consumed in degrading the engine. Then the life of the engine is an inverse function of its power output. This is a result of the following four conditions:

1. There is always an energy loss in every operating engine. This is a requirement of the Second Law of Thermodynamics.

2. Perfect materials do not exist; it is inevitable that some of the energy loss is irreversibly dissipated in the engine structure.

3. The absorption of energy by the structure does work on the structure. This is a result of the First Law of Thermodynamics.

4. The work done on the structure results in damage which accumulates to some characteristic value at which failure occurs. The constant of proportionality depends on the properties of the material that is degrading, the fraction of the output energy/cycle that goes into deterioration, and the total degradation allowed before failure occurs. It should be noted that, by proper choice of coefficients, repair can be accounted for. The thermodynamic approach states that every aging process derives from the above three factors and the power output.

Examples are given of the application of this theory to failure by friction (including bearings), to failure where the parameters are statistically distributed, to human mortality, etc. The human mortality curves indicate that the life span may be limited by one wearout mechanism. All the major body components in man and animals are self-repairable except one--the nervous system. Nerve cells that die are not replaced after infancy. A wearout mechanism in animals is therefore one associated with deterioration of the nervous system. Death rate curves by sex show that females tend to live somewhat longer. Since the basal power of adult males is approximately 20% greater than that for adult females, the 10% greater mean life of females in 1959 is accounted for. The common attribution of lower female mortality

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

to a superior structure is seen to be a misinterpretation. (Author in part)

REVIEW: No doubt the idea of a functional dependence between aging and level of operation is applicable, in a pragmatic sense, to many cases of aging and failure. However, as a result of the usage of thermodynamic terminology and thermodynamic laws in the course of the derivations, it is easy for the casual reader to be left with the quite erroneous impression that the developments and conclusions of the paper are subject to comparable standards of validity and general acceptance as are the laws of thermodynamics. A few examples of the difficulties are:

1. The concepts of energy, work, and heat are confused in the paper. The term "energy" is used sometimes when "work" is meant. Thus in point 3 (see ABSTRACT, above) heat is completely ignored and the statement is incorrect. Also, in the text, "... Every transformation of energy in nature incurs losses, i.e., efficiency is always less than 100%. This is a requirement of the Second Law of Thermodynamics ..."; obviously work can be entirely converted to heat with no trouble.

2. The concept of a heat engine cycle is confused with a machine. Thus "... consider the familiar Carnot cycle ... performed by a lossless engine .... Because the engine is lossless, there is no deterioration. Life span is infinite."

3. The formula for life span as an inverse function of power is derived on the basis of a heat engine. Not all devices are heat engines; for example, electric motors, fuel cells, the brain. Yet the formula is claimed to apply to everything (including the brain).

4. The formula (life span as an inverse function of power) would be difficult to check in any event. Power is poorly and contradictively explained (for example, in the derivation power is rate of work output, while in the bearing application it is the friction losses), so that it would be difficult in any particular application to know whether input, output, losses, etc. were meant.

Attention to thermodynamic standards would probably have resulted in the assumption that the rate of degradation of a structure depends in some way upon its rate of entropy production. Such a statement of the basic hypothesis of the paper would be more general, more explicit, and preferable to the one used. Any such hypothesis should be regarded as such, however, and not imbued with the aura of general applicability usually attributed, say, to the laws of thermodynamics or mechanics. At best, one can expect from such an approach the elucidation of a possible failure mechanism which often fits experimental evidence; to look for a "general theory applicable to any physical structure" along the lines of the subject paper seems excessively ambitious. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of flowgraph techniques to the solution of reliability problems

AUTHOR: W. W. Happ, Hughes Semiconductor Division, Newport Beach, California and Arizona State University, Tempe, Arizona

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 375-423 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To illustrate the need for and to present an introduction to flowgraphs.

ABSTRACT: Flowgraphs are one of many ways of describing physical systems. Rules for the application of flowgraphs are presented and illustrated. A large number of engineering problems in reliability can be described by a few basic patterns. The use of flowgraphs can aid in revealing these patterns. About 120 references to the literature are cited.

REVIEW: One important aspect of system reliability analysis is that of providing a functional description of the system. Flowgraph techniques are one of many important tools available for simplifying this process; however they are frequently neglected because they are not understood by practicing engineers.

This paper is a concise introductory treatment of flowgraph theory and includes many examples of application to physical situations. The paper will probably be of greatest help to those readers who have previously had a brief introduction to the subject, but it will also be of interest to technical personnel having more experience.

The subject of flowgraphs was treated extensively by the same author in the paper covered by Abstract and Review Serial Number 711. In that paper there was more emphasis on the use of flowgraphs as a reliability analysis tool. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1508 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Identification and elimination of a failure mechanism in semiconductor devices

AUTHORS: T. A. Longo and B. Selikson, Sylvania Semiconductor Division, Woburn, Massachusetts

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 424-435 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To identify a cause of open lead failure in semiconductor devices and to prescribe a proven, effective remedy.

ABSTRACT: Thermocompression bonded gold wires are commonly used for joining the aluminum ohmic contacts on silicon devices to the leads of the package. Accelerated life tests at 300°C reveal the formation of a black-purple material around the junction between the gold wire and the aluminum contact which is mechanically weak and electrically resistive. This material is thought to be basically $AuAl_2$ which contains some silicon. By using aluminum wires in place of gold wires, the formation can be avoided at the silicon surface, although a purple formation now appears at the joint between the aluminum wire and the gold-plated Kovar post of the package. The latter material contains no silicon and is much less objectionable than the original ternary alloy. This fact has been proved by comparative tests of electrical resistance and bond strength between gold wire and aluminum wire units.

A ternary Al-Au-Si phase diagram is postulated from the three available binary phase diagrams.

REVIEW: This paper is a good discussion of the well publicized problem called purple plague and of a practical, straightforward solution to it. The reader may be made a bit uneasy by the admission (and photographic proof) that the problem has not been completely eliminated. Purple areas still form between the aluminum wires and the gold posts on the header. But the results of the test data presented here and, perhaps more significant, the statement that the authors' production facility is now using aluminum wire bonding exclusively may be evidence enough that the problems associated with purple plague at the header posts are not major.

A configuration not specifically mentioned but of considerable interest in integrated circuits is that of a gold thermocompression bond to an aluminum pad which is deposited on top of an oxide

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

layer rather than on top of bare silicon. If the absence of pure silicon in the immediate vicinity of the gold-aluminum alloy interface reduces the purple plague formation, then an alternative solution, which avoids the "tricky" aluminum-aluminum bonding operation, might be the rather straightforward use of short lengths of deposited aluminum interconnections between the silicon contact area and the point out over the adjacent oxide at which the gold lead is bonded.

In the description (on p. 433 in the paper) of the experiment to find the ternary eutectic, the starting point is given as the aluminum-silicon eutectic to which gold will be added. It would appear that the starting eutectic temperature of aluminum-silicon should be 577°C (from the accompanying phase diagram) rather than 370°C as stated in the paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1509
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of gaseous optical masers using noble gas active media

AUTHOR: Jack E. Taylor, Quantum Physics Laboratory, Research Department, General Dynamics/Electronics, Rochester, New York

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 436-449 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To discuss some of the degradation mechanisms in a neon-helium laser.

ABSTRACT: Lasers are fairly new and there is no body of knowledge on their long-term behavior. The following two failure/degradation mechanisms were studied: (1) window scattering losses, and (2) contamination due to oxygen. The window scattering losses are increased due to contaminants from the atmosphere settling on the window. The rate of increase of loss due to this effect was measured in an office-laboratory environment. The gas fill can be contaminated by outgassing, leaks, changes in leak rate outward of the fill gases, etc. The contamination studied here was the calibrated introduction of oxygen, which is likely to be a common contaminant. Oxygen is "cleaned up"--probably due to the gas discharge--by a short-term and slower long-term mechanism. Part of the effect is reversible when the laser is on and off.

Hopefully, studies of this sort will lead to prediction of the life of lasers by means of a few simple measurements.

REVIEW: Papers of this sort on new components are more than welcome. The author is to be congratulated on his beginning work in this area. It would indeed be valuable if, from a few measurements, the life of a gas laser could be reasonably well predicted. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Silicon surface passivation: materials and micro properties

AUTHORS: J. W. Dzimianski, E. R. Pemsel, W. J. Lytle, and S. M. Skinner, Air Arm Division, Westinghouse Electric Company, Baltimore, Maryland

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 450-466 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To apply the stick-slip probe method to the study of crystallinity in silicon oxide grown on polished silicon surfaces.

ABSTRACT: Crystallinity in the SiO_2 layers used for the protection and passivation of silicon planar devices is undesirable and is indicative of potential failure. To recognize such areas the stick-slip method of measuring surface charge and surface frictional forces is used (see Abstract and Review Serial Number 1342). In this application the probe is dragged across a silicon specimen; the specimen has bare silicon adjacent to a beveled region of silicon oxide. The boundary between the silicon and the silicon oxide is identified by the charge transfer trace going to zero when the probe passes from the silicon surface to the SiO_2 surface.

The beveled SiO_2 specimens are prepared chemically by a meniscus etch technique in which the angle between the plane of the wafer and the normal to the surface of the liquid etchant is used to control the angle of bevel. In this process the collapse of the meniscus signifies either the end or the beginning of the end of the etching step. The distinction between the "meniscus etch" and the "depletion layer meniscus etch" is that in the latter etch the wafer remains in the solution several minutes after the meniscus has collapsed so as to permit the solution clinging to the oxide to react to saturation.

The frictional drag forces of a surface depend upon chemical constitution and crystallinity which the stick-slip measures. Correlations between the visually identifiable defects of the specimen and changes in the frictional trace are good.

REVIEW: The use of a mechanical probe to detect oxide crystallinity is not an obvious approach, particularly when the size of the crystallites may be at least an order of magnitude or so smaller than the probe radius. In general the results reported here

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

indicate only areas of crystallinity rather than point crystallites. The stick-slip probe can unquestionably provide much information about a surface, as is shown; but to attempt to solve what can be a microscopic-scale problem with macroscopic tools may prove difficult.

The advantages of the particular angle etch technique employed in this work over more conventional angle etches are not made clear. The more straightforward method of slowly withdrawing the wafer from the etching solution seems to result in a linear wedge [1] and at the same time would appear to be free from the artifact crystallinity caused by material redeposited from the saturated etchant.

In a private communication, the authors have made the following comments on the above ABSTRACT and REVIEW.

"(In the) first paragraph of abstract, fourth line, you refer to surface frictional forces. This is correct as per the article. Later work has shown that what is involved is not frictional force in its common usage. It is adhesion between the probe and the surface, consisting of independent adhesions and breakfrees, and that what is measured is (1) the rate of increase of adhesive force, and (2) the breakfree force, rather than the overall summed effects of many of these which would be true friction. Suggest therefore that the words surface frictional forces be replaced by adhesion of probe to surface.

... the comment about the probe being larger than the sizes of heterogeneities being measured. This point has been specifically considered in the second quarterly report on Contract No. AF30(602)-3017, and it has been shown that since the quantity being measured is the electrical flow which is summed up over all portions of the probe in contact with the surface, the probe will delineate heterogeneities of dimensions down to less than 1/1000 of the dimension of the probe. Therefore the question is not a solving of a microscopic-scale problem with macroscopic tools. This question has been misinterpreted by others and the proof has now corrected this misconception."

REFERENCE : [1] L. A. d'Asaro, "Diffusion and oxide masking in silicon by the box method," Solid-State Electronics, vol. 1, 1960, pp. 3-12 ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Missile failure due to impurities in electroplates

AUTHOR: Paul Mahler, Consultant, Rockwood Heights, Apt. 28, Rockaway, New Jersey

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 467-475 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To show that vacuum ultrasonic treatment can clean plated contacts well enough to prevent failures due to contaminants in the plating.

ABSTRACT: This paper purports to show:

1. That the surface layers of commercial electroplates are porous and therefore must contain absorbed matter, to be called absorbates for short.
2. That because of this situation a sealed switching device whose contacts contain absorbate cannot be considered reliable.
3. That the so-called Vacuum Ultrasonic Treatment (VUT) will reduce the amount of absorbate left in pores quickly and economically to the point where circuit failure due to absorbate could not possibly occur.
4. That the VUT makes it possible to use a radioactive tracer technique for the nondestructive determination of the porosity of any coating.
5. That (a) the removal of absorbate should greatly increase the strength of the bond between solder or weld metal and the surface of any electrodeposited film, and (b) flux should not be required when the soldered joint is made on gold electroplate.
6. That more work needs to be done to establish:
   a. The minimum thickness of copper and nickel, the base metal plating, and of gold, the protective coating, which would resist the attack of a water-saturated mixture of air and hydrogen sulfide.
   b. Which gold platings, meeting condition 6a, would tend to cold-weld to no greater degree than conventional gold plating.
   c. What process conditions would assure that the pores in every electroplated piece are continually flushed with cleaning solvent during the VUT. (Author)

REVIEW: This paper is concerned in depth with one aspect of failure. Such studies are necessary on "minor" effects, since, as higher reliability is demanded and achieved, heretofore "minor" problems

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

become major ones. The author appears to have done much work in support of his main thesis and has made a valuable contribution.

A criterion for reliability advanced in this paper states essentially that if a failure mode can be conceived, the missile is unreliable until the mode is eliminated. This is not a very convenient or operational definition and is largely a matter of degree. The point is important, however, and all possible modes of failure should be studied--naturally one will begin serious effort on the phases judged to be most important. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1512 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Stacking faults and failure of silicon devices

AUTHOR: H. J. Queisser, Shockley Laboratory of Clevite Transistor, Palo Alto, California

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 476-482 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To discuss the structure and formation mechanisms of stacking faults and their effect on the reliability and performance of silicon devices; to suggest countermeasures for avoiding these deleterious effects.

ABSTRACT: Stacking faults are two-dimensional defects (common in epitaxial silicon layers), most of which originate at the epitaxial film-substrate interface. In the (111)-plane the faults grow as tetrahedra with the apex at the film-substrate interface. The edges of a stacking fault tetrahedron are stair-rod dislocations and it is at these edges that most of the deleterious electrical effects associated with stacking faults occur.

The origin of the nucleation centers from which the stacking faults grow is not known, but impurities such as silicon oxide at the interface are thought to be a possibility. Stresses and mechanical damage also promote stacking fault density which, other factors being equal, tends to be greater on (111)-oriented substrates than with other orientations.

The principal detrimental electrical effect is microplasma breakdown at the stair-rod dislocations, an occurrence similar to that reported previously at dislocations in non-epitaxial silicon (see Abstract and Review Serial Number 1367). Not all stair-rod dislocations exhibit microplasma breakdown, suggesting that an additional condition is needed--most likely the presence of a dielectric precipitate such as silicon oxide. Metal precipitates also tend to gather at stair-rod dislocations, causing soft I-V characteristics as previously reported.

To avoid these undesirable effects several countermeasures are recommended:

1. Careful preparation of substrates including gaseous etching immediately prior to epitaxial deposition.
2. Substrate orientation other than (111).
3. Inverse epitaxy in which the epitaxial layer is used only as a low resistivity supporting substrate for devices fabricated

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

in structurally superior parent silicon.

REVIEW: This pithy paper summarizes contemporary thinking with respect to the quality of epitaxial silicon. The text is clear and concise and includes adequate references for amplification of the many statements which are made briefly. The presentation rings with authority and, coupled with the author's refusal to waste words, makes for refreshing reading. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure modes and mechanisms in solid tantalum capacitors

AUTHORS: E. J. Fresia and J. M. Eckfeldt, Sprague Electric Company, Engineering Laboratories, North Adams, Massachusetts

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 483-497 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To discuss failure modes and mechanisms in solid tantalum capacitors.

ABSTRACT: Both the catastrophic and leakage current increase failure modes are directly associated with the current flickering phenomenon peculiar to the solid tantalum capacitor. These current bursts are themselves associated with imperfections in the tantalum oxide film. Imperfections or flaws can arise from several sources such as impurities (both metallic and gaseous) in the base metal, surface geometry of the metal, physical damage to the oxide, or thermal cycling of the metal-oxide during processing. Localized heating within microscopic flaws due to relatively high current flowing through such sites can account for leakage current rises and also subsequent flickers, assuming an energy barrier has been exceeded which allows a sudden avalanche flow of current to occur. Surges which occur with no apparent gradual leakage current increase are difficult to explain, but one can consider such possibilities as slow chemical reactions at extremely small areas or field-induced diffusion of ions and/or vacancies in the oxide. Occurrence of either failure mode can be reduced or eliminated by various combinations of applied voltage, environmental temperature, or circuit resistance.

Infrequently failures due to increases in capacitance and/or dissipation factor are found. A defective hermetic seal which allows moisture to enter the unit is the most common cause for such failures. Since more of the available tantalum oxide surface is contacted by the moisture than is by the MnO_2, the capacitance shows an increase. The increase in dissipation factor results from an increase in the resistivity of the MnO_2 due to the presence of moisture. Application of reverse potential to this component can also cause an increase in both parameters by changing the conductivity profile of the dielectric such as to decrease the effective thickness and thereby increasing the capacitance and dissipation factor.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

The dissipation factor has also been found to increase with time due to (1) a cold solder junction between the pellet and can, and (2) failure to apply the carbon layer between the MnO_2 and the metallic cathode coat.

Failures due to mechanical problems are rare and the causes obvious. (Authors)

REVIEW: This is a good report of what appears to be good work. This type of intensive effort is very valuable in improving the life of components. Other papers on solid tantalum capacitors have been covered by Abstracts and Reviews Serial Number 173, 586, 1351, 1411, and 1469. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1514 -1
Codes 835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure modes in integrated and partially integrated microelectronic circuits

AUTHORS: G. P. Anderson and R. A. Erickson, UNIVAC, St. Paul, Minnesota

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 498-524 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To describe observations of failure modes in integrated and partially integrated microelectronic circuits.

ABSTRACT: A natural extension of UNIVAC's intensive failure mechanisms studies on standard computer components has been the work done on integrated semiconductor circuits. Virtually all the problem areas discussed have been observed rather commonly throughout the semiconductor industry. Among these are foolish failures which result from the simplest errors of omission or commission, and can occur in virtually any kind of device. A fortunate attribute of the "foolish failure" is the fact that its very nature usually makes it easy to catch using only routine measurement or screening techniques. Most of the following examples are of this type.

1. A corrosive contaminant was sealed into the unit, such that the resulting reaction proceeded for more than one year before the thinly deposited conductor was etched through.

2. An integrated device failed because a diffused resistance element opened as a result of progressive cracking in the silicon substrate material.

3. A notorious time-temperature dependent failure mechanism is the well known intermetallic reaction now generally called "purple plague".

4. A "simple" error in the photolithographic process which defines the circuit caused a thin bridge between land areas in the deposited aluminum circuitry and was responsible for a short.

5. In the case of two "failed" memory units, the indexing marks which establish the external lead position had been attached to the wrong side of the package.

6. Unnecessary failures of integrated circuits often result from the inclusion of "junk" inside the package.

7. An example of a photolithographic process deviation involved a diffused resistor which was shorted between loops.

8. Solder blobs from the cap sealing operation were found to be in contact with the internal leads such that even small stresses due to temperature cycling were sufficient to produce intermittent contact and shorts.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

Other examples of failure causes are cited. It is concluded that integrated semiconductor circuits are subject to the failure modes present in the planar transistor as well as others connected with novel packaging and interconnection techniques. Failure analysis of the type discussed tends to remind and harass the vendor into a continuing product improvement and surveillance effort. (Authors in part)

REVIEW: This is a good paper, well worth the time to read for those interested in the reliability of microelectronic devices. The classification of "foolish" failures is one which is particularly suited to a number of the observed causes of failure. One would hope that as these unnecessary causes of failure are eliminated, certain inherent failure modes which are not treated in the paper could be identified, if they exist. For example, the serious degradation problems associated with surface passivation are not discussed, primarily because the failure modes which are discussed screen the slower mechanisms. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1515
Codes 775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Observations of the physics of failure of semiconductor devices by X-ray radiography

AUTHOR: Ray L. Silver, Delco Radio Division, G. M. C., Kokomo, Indiana

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 525-534 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To illustrate the benefits of an X-ray radiography facility in a failure analysis program.

ABSTRACT: A new application of an old inspection tool has placed X-ray radiography in a major role in the observation of the physics of failure phenomena in semiconductors. This nondestructive method, commonly used for the observation of mechanical discrepancies, has been extended in scope to include the observation of effects of electrical failure. This has been made possible by the fact that a majority of semiconductors are mechanically bonded with solders composed of materials highly absorbing to X-rays. Thus one can distinguish solder layers from other internal elements. For this reason an evaluation of solder bond quality can be accomplished by observing voiding within these bonds, and radiographic analyses can be used to observe solder disturbances caused by electrical and/or thermal failure modes. Equipment required to perform radiographic analyses need not be elaborate, as standard radiographic film methods are used to obtain an equivalent pentrometer sensitivity of two per cent. Accelerating potentials of 150 KV maximum and exposures up to 5000 milliampere seconds have been adequate for up to .20 of an inch of copper. Optical instrumentation techniques and photographic accessories facilitate the examination and documentation of radiographs to magnifications of twenty diameters. (Author in part)

REVIEW: The application of the technique described in this paper is largely illustrated by examples from power devices where low contact resistance and good contact uniformity are quite important. Voids within bonds or inadequate surface wetting of the contact alloy can be identified and are shown to be capable of initiating electrical breakdown of the power device. As a tool for checking solder and contact quality, X-ray radiography seems to be quite effective. The detail of the radiographs in the text is not very great, however. While the inexperienced reader can probably be expected to realize that the radiographs are of semiconductor devices rather than eye teeth, not a whole lot more can be assumed. Meaningful interpretation is dependent upon experience. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1516
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure modes in Naval electronic equipment

AUTHOR: J. H. Brun, U. S. Naval Applied Science Laboratory, Naval Base, Brooklyn 1, New York

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 535-549 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To describe different modes of failure in Naval electronic equipment, together with appropriate corrective action for them.

ABSTRACT: Six major categories (somewhat overlapping) of the cause of failure in electronic equipment are: manufacturing defect, design defect, misapplication, associated failure, miscellaneous (e.g. old age, mishandling), and indeterminate. Examples given include the following:

1. Not checking the temperature variations in an equipment. Many temperatures were much higher than expected.
2. Not all parts procured to the same specification or even with the same type number are the same. "Improvements" that have not been thoroughly checked can cause problems.
3. Defects in design are all too common.
4. Carelessness during manufacture causes defects which are very aggravating.

The examples in the text are specific and well discussed.

REVIEW: This is a good paper in that it reminds engineers that many failures could easily have been prevented had there been more attention to detail. Abstract and Review Serial Number 1514, which covers another paper from the same source, refers to these failures as "foolish failures"--a very apt term. A very large portion of defects would never occur had the existing knowledge actually been used at the time of design and manufacture. "Painstaking attention to detail" must be implemented literally if adequate reliability is to be achieved. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1517 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Important mechanism contributing to tunnel diode failure

AUTHOR: R. P. Nanavati, Syracuse University, Syracuse, New York

SOURCE: Physics of Failure in Electronics Volume 2, edited by M. E. Goldberg and Joseph Vaccaro, RADC Series in Reliability, 1964, pp. 550-559 (book available to qualified requesters from the Defense Documentation Center as AD 434329; other requesters may order copies from the Office of Technical Services, Department of Commerce, Washington, D. C., price $7.00)

PURPOSE: To propose a theory for GaAs tunnel diode deterioration which can be extrapolated to other junction structures.

ABSTRACT: The problem of rapid failure of GaAs tunnel diodes under conditions of bias greater than the valley voltage has raised serious questions about the extensive use of compound semiconductor materials in general. Studies of GaAs tunnel diodes and their possible mechanism of failure have been undertaken and a tentative explanation of tunnel diode failure has been reported (see Abstract and Review Serial Number 1372). The objective of this work was to extrapolate some of the results and some of the understanding of GaAs tunnel diode failure to an explanation of failure mechanisms in other devices involving other compound semiconductors or highly doped p-n junctions.

The following two conditions are proposed as sufficient to cause failure of tunnel diodes:

1. A sufficient source of energy must be available within the device to create crystal defects by removing host and/or impurity atoms from their normal lattice sites.
2. The electric field intensity in the transition region must be high enough to move these atoms across the transition region.

In addition, it is assumed that there is a deterioration threshold below which self-healing of defects proceeds faster than defect generation. This theory is supported by a variety of experimental data which indicates that the energy source is internally-generated photons.

If the proposed theory is correct, then the following are undesirable characteristics of material for tunnel diodes: (1) direct (transitions), (2) wide band-gap, (3) high diffusivity of moving ions in the crystal, and (4) high doping levels. The theory needs further checking on tunnel diodes made from other materials. (Author in part)

REVIEW: The weight of experimental observations in support of the proposed

deterioration mechanism is strong. As pointed out, plausibility has been shown, but the theory is not proven. The contradictory evidence from GaSb tunnel diodes is noted. This article is a noteworthy contribution to the solution of this failure problem and gives cause for concern for the use of compound semiconductors such as GaAs for high-temperature semiconductor devices. ##

Serial Number 1518
Codes 716;774;782;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A report of the proposed IEEE test procedure for the evaluation of insulation systems for electronic power transformers

AUTHOR: G. I. Duncan, General Electric Company, Fort Wayne, Indiana (for IEEE Materials Subcommittee of the Electronic Transformers Committee)

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 279-289

PURPOSE: To describe a test procedure which establishes a uniform method for comparing the lives of electronic transformer insulation systems.

ABSTRACT: A test procedure, in which thermal degradation has been chosen to be the major factor affecting the life of insulating materials, has been devised for evaluation of electronic transformer insulation systems. Other environmental factors such as vibration, thermal shock, and moisture have been included to simulate operating conditions. These factors have been chosen in such a way as to develop and disclose promptly any significant weaknesses during the temperature aging of an insulation system.

Section 1 describes the types of insulation specimens suitable for use in the tests. Section 2 recommends the test cycle consisting of environmental and electrical stresses designed to represent the cumulative effects of long service under accelerated conditions. Section 3 gives information on establishing the criteria of failure, methods for analyzing test results, and a guide for interpreting test results.

REVIEW: This recommended test procedure for electronic transformer insulation systems shows a great deal of thought and planning. The paper is quite complete, clearly written and thoroughly detailed. In most cases, the procedure can be followed directly with no change; however, guidelines are offered for variation as may be necessary for particular situations not covered. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1519
Codes 716;774;782;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A problem associated with the evaluation of insulation systems for electronic power transformers

AUTHOR: E. N. Henry, Senior Engineer, Aerospace Division, Westinghouse Electric Corporation, Baltimore, Maryland

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 290-298

PURPOSE: To describe a variation in "The Proposed IEEE Test Procedure for the Evaluation of Insulation Systems for Electronic Power Transformers" necessitated by an abnormal condition created by accelerated life tests in sealed transformers containing cellulose insulation.

ABSTRACT: Sealed transformers which contain cellulose insulation often cannot be subjected to the temperatures required by "The Proposed IEEE Test Procedure for the Evaluation of Insulation Systems for Electronic Power Transformers" without preconditioning. The cellulose insulation undergoes a chemical breakdown, principally producing water in an amount and at a rate proportional to the temperature. This water may form deleterious acids, produce leakage paths which cause localized heating, or create steam pressure which literally blows the structure apart. High voltage systems are more susceptible not only because of the greater quantity of cellulose, but also because of dielectric heating in the insulation which produces water faster and contributes to runaway.

A method of preconditioning which has a minor effect on the standard test results, but yet permits otherwise impossible comparison evaluations, utilizes creation of escape paths for the water and operation of the transformers with a minimum of voltage at start-up.

REVIEW: This paper presents an intelligent application of a standard test procedure in an unusual situation. The author makes an excellent analysis of failures which might easily have been taken as the result of normal aging. His recommendations are well thought out, and he offers a meaningful variation on the standard procedure. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1520
Codes 782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic component parts failure rates and failure mechanism research in the United Kingdom

AUTHOR: G. W. A. Dummer, Royal Radar Establishment, Malvern, England

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 333-351

PURPOSE: To present findings of failure studies in the United Kingdom.

ABSTRACT: The Royal Radar Establishment has conducted a study of failure rates for electronic equipment and component parts since 1944. Data on failures in early equipment are shown. Failure mechanisms in specific component parts, particularly resistors and capacitors are discussed; the importance of the environment is demonstrated.

REVIEW: The complexity of the reliability problem is demonstrated in this report, which presents a summary of findings from nearly 20 years of failure research. Detailed information is given on methods of data collection and testing; and a succinct summary of results is provided in tabular form. An interesting feature is a section listing individually the effects of high humidity, high temperature, and low temperature on 32 types of component parts. The author is to be commended for his fine organization of such a tremendous amount of diverse information. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1521
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life performance history of Minuteman design dipped mica capacitors

AUTHOR: Arthur W. Evans, Manager of Engineering, The Electro Motive Manufacturing Company, Inc., Willimantic, Connecticut

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 352-357

PURPOSE: To describe a reliability testing program for dipped mica capacitors.

ABSTRACT: Previous tests performed on dipped mica and molded mica capacitors yielded a relationship between failure rates of the two types and provided data on the variation of failure rate with physical characteristics and environmental factors. For a ratio of applied-to-rated voltage not greater than two, the capacitor lifetime is inversely proportional to the eighth power of the ratio.

Subsequent testing of the dipped units at 2.25 times rated voltage at 85°C produced no failures in 65×10^6 unit-hours. In life tests on 5484 units taken from production lots, all remained well within specifications.

At the start of another life test at 125°C on 5100 dipped mica units in three groups at different electrical stresses, predictions of failure rates were made from earlier findings. Data on average cumulative percent failure with time were used in statistical calculations to give a 90% confidence level. Failure of two units in one group by 1000 hours permitted calculation of an actual failure rate and a correction factor for predicted values. Times of first failure computed for the two remaining groups from adjusted failure rates were subsequently verified within 5%.

REVIEW: This paper discusses some interesting statistical calculations based on life test data. The author has well anticipated questions on his work and has left no assumptions unjustified nor apparent anomalies unexplained. The high accuracy of his predictions is certainly impressive (and probably fortuitous); more examples would have been helpful. A number of arithmetical errors appear in the paper but none are of serious consequence. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1522
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Specific techniques to be used in developing hi-reliability connector specifications

AUTHOR: J. D. Ekings, Quality Control and Reliability Manager, Burndy Corporation, Norwalk, Connecticut

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 358-366

PURPOSE: To review specific techniques recommended by the EIA Connector Reliability Panel for upgrading military connector specifications.

ABSTRACT: Inherent structural differences between connectors and other passive electronic parts have caused the connector industry to lag behind in setting up quantitative measurement of reliability. Current test programs are designed to evaluate the capability, but not the reliability, in achieving specific performance levels after application of a stress. Predicting performance for an extended period of time is impossible with this technique. Predictions can be made if basic strength testing and statistical data are analyzed. The increase in cost which might be necessitated by test equipment of greater capability would be negligible in terms of assurance gained in the design.

Qualification testing should be broadened to include evaluation of reliability. A demonstration program should require proof of meeting standard failure rates at a 60% confidence level. Failure criteria should include degradation in insulation, mechanical coupling, and electrical conductivity all measured under environmental stresses. While implementation of a quantitative reliability program is highly desirable, it poses risks to manufacturers in terms of present product lines and inventories.

REVIEW: The author's primary emphasis on the topic of connector reliability is placed on the upgrading of military standards; familiarity with military specifications is essential to an appreciation of the paper. Readers who are interested in connector reliability for its own sake are apt to be tired out by the lengthy discussions relating to the military program.

The case for quantitative measurement of connector reliability is certainly to be commended, but greater impact could have been generated by a more succinct presentation of the problem and recommendations. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1523
Codes 715;782;835;
844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Calculation of optimally reliable solar cell arrays

AUTHORS: R. A. Brenan and F. D. Mason, Hughes Aircraft Company, Culver City, California

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 367-377

PURPOSE: To discuss the physics of operation and failure of solar cells and to derive a formula for the degradation of an array due to open circuits.

ABSTRACT: Solar cells are silicon p-n junctions which use the photoelectric effect to provide electrical power from the sun's radiation. Some of the radiation causes gradual degradation of the cells. Other particle radiation and micrometeoroids cause degradation and catastrophic failures. The analysis in this paper is limited to the occurrence of open circuits and the failures are assumed to follow a Poisson process. The cells are assumed to be in a parallel-series string, i.e., n cells in a parallel set and m such parallel sets in series. A formula is derived, on the basis of probability, for the output current in terms of the failure probabilities of the cells; curves are shown.

REVIEW: While not all the mathematics was checked, the results appear to be good within the limitations of the analysis. The Poisson limitation is actually used only in a few of the scales on the graphs; in general, only the statistical independence assumption is needed for the analysis. When the paper was given, the authors stated that they were working on an analysis which would incorporate short circuits. The approach in this paper is somewhat different from that in many others on this subject since the parameter of main interest here is the expected value of current as a function of the total number of failures in the array.

Other papers on the reliability of solar cells have been covered by Abstracts and Reviews Serial Numbers 651, 743, 764, 775, and 1155. ##

Serial Number 1524
Codes 775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Prediction of diode degradation in transistors by measurement of time response

AUTHORS: J. R. Bevington and M. E. Stanton, Delco Radio Division, General Motors Corporation, Kokomo, Indiana

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 378-384

PURPOSE: To present a technique for predicting transistor failure due to diode degradation.

ABSTRACT: A significant indicator of the probable failure of germanium alloy power transistors due to collector diode degradation is the time response of the diode leakage current to a step application of rated reverse voltage. In tests on 449 transistors, failure occurred in 74.8% of the 131 devices whose collector leakage current showed a slow rise and subsequent fall (after decay of the initial spike). Only 3.46% of the 318 devices failed without showing this behavior. Use of this indicator for a screening technique would have reduced the failure probability for this test group from 24.2% to 3.46%.

The "climbing" phenomenon can be explained by the transient formation of an accumulation layer and an avalanche-limited breakdown of the junction near the surface. Improved process techniques suggested by the model have been made standard on all Delco Radio high-reliability germanium power transistors.

Advantages of this technique over the "burn-in" method for sensing initial phases of degradation are the short time required (less than 15 seconds) and the minimization of stress during test.

REVIEW: The authors have discovered a phenomenon which might well justify more quantitative study than is presented here. Certainly any short, non-degrading technique which is useful for failure prediction is a boon to industry and should be understood thoroughly. Some comment on the applicability of the technique to other types of transistors would have been a welcome addition to the paper.

The report is well written; indeed, its organization and clarity could well serve as a model for many authors. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1525
Codes 771;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Approach to developing electrical connection comparison data through variables testing

AUTHORS: R. A. Geshner and B. Tiger, Defense Electronic Products, Radio Corporation of America, Camden, New Jersey

SOURCE: Proceedings 1964 Electronic Components Conference, sponsored by IEEE and EIA, with participation of ASQC, Washington, D. C., May, 1964 (IEEE Transactions on Component Parts, vol. CP-11, June, 1964), pp. 385-393

PURPOSE: To propose a method for determining the reliability of electrical connections through generation of continuous-variables data.

ABSTRACT: The measurement of reliability of electrical connections by conventional life testing techniques is prohibited by the excessive time and cost required. A new approach uses the methods of statistical quality control with continuous-variables data generated by a "Stress-Survival Matrix Test" to determine the fraction defective. This test exposes quantities of similar devices for specific times (cells) to carefully determined combinations of environmental factors (treatments). At the end of each exposure, measurements are made on performance and catastrophic variables. Other tests obtain data under the effects of non-interacting environments. The problem of transforming fraction defective estimates, derived from the Stress-Survival Matrix Test, into reliability functions of time is receiving further study.

REVIEW: This approach to testing is a good and useful one. While the concept of matrix tests is certainly not new, the possibility of planning a matrix test to yield a set of continuous-variables data which can be transformed into a reliability function of time had not received widespread consideration. While it is true that with this approach less testing is required for a given accuracy of the estimators, it is also true that if a distribution is to be assumed it must substantiated. This requires a great amount of previous testing to establish the distribution and/or ability to control (statistically) and measure the production process. In the absence of such substantiation, it may be necessary to estimate fraction defective by non-parametric methods. (The reader should be aware that he does not escape this problem of required knowledge of the underlying distribution when he resorts to any of the current life test approaches.) Although the authors most wisely caution about making predictions too far out on the tails of a distribution, they state "There may be a practical need to extend such (Gaussian) tables beyond 10 or more standard deviations". It is unfortunate that they did not clarify the meaning of "practical need". Under no stretch of the imagination is any real set of physical attributes known to be Gaussian out even half that far. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1526
Codes 612;814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Value, choice, and decision

AUTHOR: Carlos Fallon, Value Analysis and Purchasing Research, Corporate Staff, Radio Corporation of America, Camden, New Jersey

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 110-118

PURPOSE: To present simple arithmetical methods for measuring value.

ABSTRACT: In order to determine the value of a complex system, it is first necessary to divide the attributes of the system into easily-handled elements such as cost, size, reliability, etc. The important attributes of each element are evaluated using a 0 to 1 scale, not necessarily linear. As an example, where mobility is important, the weight of the heaviest part may have a value 0 if the weight exceeds 330 pounds and a value of only 0.2 if it is 175 pounds; a 50 pound weight in this case is given a value of 1. Each of the attributes is given a normalized weighting factor. The various options can then be given a net value for each attribute. In turn each attribute can be given a normalized weighting factor and the total value can then be determined for the various options. Further analysis will uncover the critical points in the system. In the end, of course, this information is used as an aid in judgment; it is not the judgment itself.

REVIEW: Within the restrictions imposed by the analysis itself (such as the linearity of combination of the elements), the methods suggested here can aid in making decisions which conform optimally to the conscious choices of the decision-maker. In any event, the process of analysis which one has to go through for this type of "arithmetical decision" is most beneficial in clarifying attitudes and opinions.

(This is not, nor is it claimed to be, the only possible quantitative aid to decision-making.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1527
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mechanical reliability in electronic systems

AUTHOR: Ian Kirkpatrick, Product Design Assurance, RCA Victor Company, Ltd., Montreal, Quebec

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 119-125

PURPOSE: To point out the difficulties involved in estimating the reliability of electromechanical and mechanical parts of electronic systems.

ABSTRACT: There are few if any good failure data on mechanical parts such as pumps and blowers. These parts usually fail by a wearout mechanism and thus their behavior is not at all well described by the Poisson process commonly used in electronics. The wearout mechanism is usually mechanical wear which in turn is basically due to friction.

A philosophy and procedure to assess the reliability level of electro-mechanical and mechanical parts was originated by RCA Victor in 1958 to make known the results of a study of the various factors affecting the reliability and operating life of mechanical parts. This report, having now progressed through six revisions, represents the current state of our analytical studies and is supported by some information solicited from a few organizations who have shown interest in this endeavour in the U. S. A. (Author in part)

REVIEW: This article does little but complain about the state of failure knowledge for mechanical parts. It gives a reference for a philosophy and procedure to be used, but does not discuss it at all. The implication that randomly-distributed failures and catastrophic failures are the same is unfortunate. For a more complete discussion of random failure see Review Serial Number 1216.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1528
Codes 770;820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Attaining confidence in spacecraft reliability Part I -- Basic concept; Part II -- Test phase

AUTHORS: Walter R. Kuzmin (Part I) and Arthur A. Daush (Part II), Hughes Aircraft Company, Space Systems Division, El Segundo, California

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 143-151

PURPOSE: To present and show how to apply a two-part test program which uses the concept of equivalent mission cycle.

ABSTRACT: The equivalent mission cycle concept is an adaption of a probability technique relating number of tests and failures to components in a system so that the overall estimation of system reliability may be made at some confidence level. For a typical spacecraft, the number of components was chosen to be 9 as the number of major subsystems. In an example cited it is indicated that 11 mission cycle tests are needed to determine if 0.75 reliability at the 80 percent confidence level has been achieved. Since the acquisition of 11 equivalent mission cycles for spacecraft is a difficult task, maximum utilization of all available data becomes a necessity. For a typical system with the scheduled acceptance and developmental tests, a deficit of several equivalent mission cycles may be expected. This would prevent practical attainment of the confidence goal for statements pertaining to the spacecraft reliability requirement. To overcome this deficit, a random selection of production hardware is made which is subjected to special testing in order to acquire the necessary additional equivalent mission cycles.

The plan provides a flight environmental time sequence for testing and delineates the environmental conditions and sequence of tests to be performed on the test specimens. Particular attention is devoted to the actual mission operating time and/or cycle which each test specimen would endure on its transit to the moon. In addition, the various units of the spacecraft are segregated into logical groups for maximum utilization of space chambers and providing of data correlation with actual system groupings on the spacecraft. Special fixtures are described which replicate the actual environmental condition expected at a unit's physical location on the spacecraft. (Authors in part)

REVIEW: This is apparently not the full paper since much of the intended description is missing. (However, it appears longer than an abstract.) A formula for the lower reliability confidence limit is given, but it is neither derived nor referenced. The ideas in the paper seem to be good, but there is not enough detail to permit a critical evaluation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1529
Code 850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An economic approach to reliability demonstration

AUTHOR: Thomas A. Simonds, Electro-Mechanical Research, Inc., Sarasota, Florida

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 156-157

PURPOSE: To show how to reduce reliability testing time.

ABSTRACT: Conventional reliability demonstration tests treat system and component alike in that those components which are so designated are tested to prove that they meet their individual reliability requirements. Here, after each tested component is proven good (or an acceptable substitute is itself proven good) the system is then tested to prove that it meets its own requirements.

This process can lead to considerable unnecessary expense, especially when one considers the fact that the system itself is the item which must demonstrate its reliability requirement. The reliability of the components are important only as they contribute to the system's reliability. Thus, it would be more efficient to test the components to weed out those which are obviously substandard and then test the systems to demonstrate that they do meet their requirements.

This can be accomplished by the application of upper and lower confidence limits to the testing. Here, the designated component test plans are based on the <u>lower</u> confidence limits of their reliability requirements, those failing being redesigned or replaced by acceptable substitutes. The system test plans are based on the <u>upper</u> confidence limits of their requirements so that definite assurance of system adequacy is demonstrated.

In summary:

1. Conventional reliability demonstration test plans are not the most economical available.
2. The amount of savings realizable by adoption of the proposed approach is considerable.
3. If one is looking for the most economical reliability demonstration test plan for his program, this is the best available today. (Author)

REVIEW: No quantitative discussion is given of the proposal, nor is it compared, say, to testing parts at a lower confidence level but still using the upper confidence limit. The problem of combining confidence levels is difficult at best; this paper makes no contribution to the quantitative aspects of the situation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1530
Code 820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A generalized mathematical method for estimating system reliability

AUTHOR: Louis Schneider, Autonetics

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 158-159

PURPOSE: To describe a mathematical model representing the life cycle of a system from assembly to degradation.

ABSTRACT: The principal limitation of the exponential distribution is that it can only be applied to debugged equipment, that is, equipment operating in the region of constant failure rate. Thus, it follows that a derivation describing the life cycle of a system from assembly to degradation would be extremely useful. This paper derives and develops a generalized mathematical model of the form $Y = AT + B\ (1-e^{-ct})$, which provides a useful tool in ascertaining at an early stage whether contractual mean-time-to-failure requirements or goals can be achieved. In addition, the model aids in determining optimum burn-in time.

The parameter estimates provide the following reliability information: (1) number of failures to be expected during any time interval, (2) state of equipment debugging, and (3) expected mean-time-to-failure and constant failure rate of equipment upon completion of the debugging phase.

A detailed demonstration is undertaken applying $Y = AT + B\ (1-e^{-ct})$ to the evaluation of the in-house performance of two typical production systems. (Author in part)

REVIEW: It is unfortunate that this paper and some others in the Transactions of the Eighteenth Annual ASQC Convention were merely abstracted and not published in full. From the information given in the Transactions, it is not possible to make a critical evaluation of the proposed model. The symbolism used in writing the equation is not even defined. A case history describing in detail its application to a typical system would have been helpful.

The author in a private communication has indicated that full text copies of the paper were distributed at the convention (but he did not say whether copies are still available). He has also stated that the full text included detailed information on (1) the mathematical derivation of the model, (2) application of the model to two typical navigation systems, (3) development of a composite curve in conjunction with non-parametric methods of determining sample size, and (4) a description of the computer program. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1531
Codes 433;551;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Confidence intervals on design improvement factors

AUTHORS: E. G. Bianco and L. K. Sarin, General Electric Company, Major Appliance Division, Louisville 1, Kentucky

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, p. 167

PURPOSE: To present confidence limits on a proposed design improvement factor.

ABSTRACT: In this paper, the authors have selected a widely used improvement factor (one that can be justified both from an engineering as well as from a statistical viewpoint) and have developed statistical confidence limits for such an estimate.

An improvement factor, E, can be defined as:

$$E = p_o/p_1$$

where p_o and p_1 are the cumulative failure rates of two designs in comparison, estimated from c_o and c_1 failures and n_o and n_1 items tested respectively. It is the purpose of this paper, then, to show that two-tailed $100(1-\alpha)\%$ limits on E can be formed as follows:

$$\text{Upper Limit} = F_{1-.5\alpha,\upsilon_o,\upsilon_1}[n_1(c_o+1)/n_o(c_1+1)]$$

$$\text{Lower Limit} = F_{.5\alpha,\upsilon_o,\upsilon_1}[n_1(c_o+1)/n_o(c_1+1)]$$

where υ_o and υ_1 are degrees of freedom for the F-distribution.

Two different estimates of E (as defined above) are discussed in light of their properties, and a recommendation is made as to the use and validity of a Bayesian statistic. (Authors)

REVIEW: It is unfortunate that this paper and some others in the Transactions of the Eighteenth Annual ASQC Convention were merely abstracted and not published in full. Perhaps in such cases the authors can supply copies of the full text to those who may request them.

This is a potentially useful result. However, the amount of information and discussion given in the Transactions is insufficient to permit a critical evaluation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1532
Code 820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determination of a lower-bound confidence limit of a specified reliability from fragmentary testing times

AUTHOR: Norman R. Garner, Quality Control Consultant, West Covina, California

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, p. 168

PURPOSE: To propose a lower-bound confidence limit for a specified reliability when the distribution of times to failure is Gaussian.

ABSTRACT: A procedure for determination of a lower-bound confidence limit of a specified reliability from fragmentary testing information is presented. The procedure assumes that time-to-failure follows a chance failure pattern which can be described by the Normal probability distribution, requires a specified reliability, R_s, for a specified mission time, t_s, and depends upon the a priori evaluation of the maximum standard deviation, σ_{max}. This information permits the derivation of a minimum mean-time-to-failure, μ_{min}. Hence, design standards for the specified R_s and t_s are σ_{max} and μ_{min}. Then, for each fragmentary testing time, t_i, a probability, P_i, of observing such a value or greater if the item tested was sampled from a population described by the design standards is computed. The estimate of the lower-bound confidence limit, γ_{LB}, is then determined by

$$\gamma_{LB} = 1 - \prod_{i=1}^{n} P_i .$$

If this value of γ is equal to or greater than the specified confidence, γ_s, then it can be asserted that the specified reliability requirements have been met. (Author)

REVIEW: This is a very brief presentation; in fact the paper serves as its own abstract. Given the assumptions which the author has stated, plus independence of the observations and the condition that the system does not fail within any of the periods t_i, the quantity γ_{LB} has the property stated in the last sentence of the above ABSTRACT. However, the extent to which it is a conservative estimate is not immediately clear. It would have been desirable to give more detail on the derivation, as well as some discussion of the properties of the estimate. The user should note particularly that the result applies to situations in which time-to-failure has a Gaussian distribution. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The undefined assumptions in acceptance sampling

AUTHOR: Ervin F. Taylor, General Electric Company, Reentry Systems Department, 3198 Chestnut Street, Philadelphia, Pennsylvania

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, p. 170 (and complete paper, 13 pp., copies of which are available from the author)

PURPOSE: To list some of the problems inherent in the sampling system as compared to the mathematical sampling plan.

ABSTRACT: Some authors, particularly theoretical statisticians, have raised a hue and cry against the rather common practice of approximating the hypergeometric distribution in calculating the operating characteristic (OC) curves of sampling plans. These authors are quick to indicate the divergence of the approximating method from the "true" method, especially for larger fractions defective.

These authors are correct from one point of view; however, they are making several assumptions about the total sampling system which are not valid in the real world of acceptance sampling. These assumptions are:

I. No distribution of lot quality exists.

II. If a defective exists in the sample, the inspector will find it (No technical human errors).

III. If a defective exists in the sample, the measuring system is sufficiently accurate to correctly identify it (No measurement error).

IV. If a defective exists in the sample and is detected by the inspector, it will be reported by him as a defective (No psychological human error).

These assumptions are usually not completely justified in practice --in fact not even to the extent that is commonly supposed. Thus approximations made in the arithmetic of the sampling plans may be negligible in practice when the total sampling system is taken into account.

It is not the intent of this paper to define some precise system for quantifying the implied assumptions in acceptance sampling. Rather, the intent is to demonstrate through a numerical example that there are numerous influences on sampling risks. The major points to be mentioned are:

1. The OC curve does not define "true" sampling risks.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

2. Approximation methods give satisfactory results for OC curves considering the "true" risks.
3. Process [probability of occurrence] curves along with the OC curve give a more valid estimate of sampling risks.
4. The "point of control" may be a more meaningful index of sampling plans than the AQL or LTPD.
5. The effects of sampling plan applications require considerable study.

Five pertinent references are cited. (Author in part)

REVIEW: Even though only an abstract is given in the Transactions, it conveys a good message clearly and emphatically. The points made by the author are excellent. As indicated under SOURCE, above, copies of the complete paper are available from the author. It is well worth the attention of those concerned with acceptance sampling in practice. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1534
Codes 750;801

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life and quality of food products

AUTHOR: E. W. Hopkins, Meat Research Section, Armour and Company, Food Research Division, Oak Brook, Illinois

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 209-214

PURPOSE: To discuss some of the problems involved in measuring the attributes of food products.

ABSTRACT: The concepts of product life and reliability are not new to the food industry. Shelf life has been an important characteristic of food ever since man first decided to save some of today's kill for tomorrow's meal. Food processors and distributors have always been concerned with the question of how long their products would remain flavorful, nutritional, and wholesome. Indeed, the entire canning, refrigeration, frozen, and freeze-dried industries exist because of the need to perserve desirable attributes of food beyond the time limits which obtain under "state of nature" conditions.

Reliability problems are problems which involve time; so are problems of food storage and shelf life. This paper seeks to define reliability as it applies to food preparation and marketing, to discuss the characteristics which must be evaluated in some manner, and to indicate the magnitude of the problems facing us. All of this is a tour of the food industry, sight-seeing rather than working. Not discussed at this time are the problem-solving phases of how and where to sample and how to judge and establish the probability levels for those characteristics which are important in food.

Each of the following measurement types is discussed: sight evaluations, texture evaluations, taste and odor. (Author in part)

REVIEW: While from the title and introduction the reader might infer that the topic has something in common with reliability engineering, the paper does not actually discuss the life of food products, but only the attributes of the food that must be measured as a function of time. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1535
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability and systems engineering

AUTHORS: Catherine D. Hock, Manned Space Flight and William Wolman, Goddard Space Flight Center, National Aeronautics and Space Administration, Washington, D. C.

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 240-256

PURPOSE: To suggest ways in which systems engineers can use the disciplines of reliability engineering and systems analysis.

ABSTRACT: The basic elements of a reliability engineering program for a complex system are generally considered to include such elements as:

a. Specification of Design Goals.
b. Assessment of Design Reliability.
c. Review and Documentation of Systems Design.
d. Specification of Preferred Parts and Materials.
e. Specification of Preferred Practices.
f. Establishment of a Testing Program.
g. Establishment of a Failure Feedback and Analysis System.

It is, of course, essential that the reliability and design engineers work together closely during the design engineering phase, so as to maximize the benefits of the reliability engineering elements to the total program. Integration of reliability engineering with production, test, and other phases is necessary to bring about a well balanced systems engineering program over the entire development and manufacturing cycle.

This program is elaborated upon in the context of designing and producing a spacecraft to launch an instrumented (unmanned) satellite into orbit, and properly receiving the transmitted intelligence. (Authors in part)

REVIEW: This is a tutorial type of paper which gathers the relevant information and presents it in a coherent and concise form. While few of the ideas, per se, are new--their organization in this paper serves a very useful purpose. The paper is, of necessity, too short to do justice to the field, but a number of references are cited for further study. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1536
Code 836

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Statistical approach to design review

AUTHOR: George Mouradian, Aerojet-General Corporation, Sacramento, California

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 275-276

PURPOSE: To describe the application of various statistical techniques for the purpose of design review.

ABSTRACT: Statistical techniques useful in a design review include the following:

1. Tolerance limits are conveniently chosen as $\pm$ 3 standard deviations.
2. A study of correlated events may lead to the identification of cause-effect relationships.
3. Analysis of variance can show which material or process is better.
4. Regression and correlation analyses are used to compare the effects of several variables.
5. Calculating the "tolerance stack-up" of many variables to determine the worst case.
6. Safety-margin analysis.

REVIEW: This is an abbreviated version of the paper; the full text as presented at the convention is available from the author. The techniques mentioned are useful. However, fine details on their application will have to be obtained from other sources. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1537 -1
Codes 122;512;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The engineering safety factor: how valid is it?

AUTHOR: S. Demskey, Re-entry Systems Department, General Electric Company, 3198 Chestnut Street, Philadelphia, Pennsylvania

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, p. 277 and paper (14 pp.) available from author

PURPOSE: To show the unsuitability of the conventional safety factor and safety margin and to introduce a new safety margin.

ABSTRACT: The conventional safety factor uses a multiplier on the maximum load; the safety margin uses a given number of standard deviations. Neither of these concepts is adequate. A new safety margin is defined as $SM \equiv (\lambda_{sm} - \lambda_o)/\lambda_o$, where λ is the failure rate, sm denotes "with a safety margin" and o denotes "without a safety margin". Examples are given of the application of these concepts to illustrate their relative usefulness. Some of the limitations of the analysis are listed.

REVIEW: The general ideas in this paper are worthwhile although some of the presentation is not very effective. The definition of SM is ambiguous at best since failure rate has no meaning in the context of the stress-strength failure model. In a private communication the author stated that by λ he meant failure probability (F), not failure rate. Then $SM \equiv (F_{sm} - F_o)/F_o$; this is a more general definition and reduces to the one in the text in the event $F \ll 1$ and λ is the average failure rate over the mission (i.e. $\lambda \equiv -[\ln(1-F)]/T$).

The old safety factor (using a multiplier on the maximum load), even though it leaves much to be desired, did serve a most useful purpose, i.e., to take into account the difference between the nominal maximum load and the actual maximum load, the difference between the nominal measure of strength and the actual strength, and to provide an actual factor of safety. All three of these are vitally important, especially in public structures. For example, in structural steel the traditional safety factor is quite large; but it takes into account the actual strength in fatigue vs. the nominal tensile strength. It also recognizes that engineers are not even capable of calculating all the exact stresses.

Part of the author's contention that the conventional safety margin and safety factor approaches are inadequate is based on the use of some tables of strength (ANC-5). It is easy, as the author does, to show that the use of these tables and some customary assumptions leads to problems in design. Perhaps the

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

best explanation of the difficulty is that the tables themselves are quite inadequate for calculations of this sort (regardless of how many people actually use them in this way).

The conventional safety margin SM_{conv} (in the stress-strength model of failure) is defined in terms of the distribution of the difference between strength and stress. $SM_{conv} \equiv \mu_d/\sigma_d$ where μ_d and σ_d are the true mean and standard deviation of the difference distribution. $F_{sm(conv.)}$ is then the portion of the distribution that lies below zero. If the true parameters are not known then the SM_{conv} is estimated using various statistical methods.

There are difficulties with both the author's SM and the SM_{conv} when very low values of F are desired. Some of the problems with the SM_{conv} are mentioned in the paper. The SM_{conv} is more readily calculated without recourse to complete knowledge of the distribution of the strength-stress difference. However, the interest usually centers around $F \ll 1$.

The use of any theoretical distribution to calculate probabilities accurately in the tail region is an exercise in arithmetic only. To calculate a probability of failure of 10^{-5} on the basis of the stress-strength model and then to assume that it applies to the real world is to be naive at best. (A more complete discussion of this point is given in Review Serial Number 131.) Thus if the shape of the difference distribution is known to stay the same when the SM_{conv} is changed, then one prefers the larger SM_{conv} (within system constraints). However, a given SM_{conv} does not correspond to the same F when the difference distributions are not the same. In general, the engineer is confronted with another of his usual dilemmas--he must make calculations and decisions on the basis of inadequate information. Just what safety margin (factor) approach should be used is difficult to say; obviously neither the author's SM nor the SM_{conv} is the complete answer. But the engineer about to use one or the other should understand the limitations of each--and they can be severe.

All in all, the paper is worth reading as an essay but not as a source of technical information. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1538
Codes 420;822;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The underlying mechanics of Weibull distribution behaviour

AUTHOR: James R. King, Computer & Data Systems, Autonetics Division, North American Aviation, Anaheim, California

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, p. 278

PURPOSE: To discuss various properties of the Weibull distribution.

ABSTRACT: An introduction discusses the elements of the Weibull probability function. This is followed by a description of Weibull probability paper and instructions for plotting data on Weibull paper. These instructions include calculation of plotting positions, gamma correction, and estimation of the Weibull parameters.

A detailed discussion of the interpretation of Weibull plots covers "quick-look" results, the problems of data adjustment and "mixed" Weibull behaviour.

Some new aspects of Weibull behaviour are considered such as non-constancy of Beta with stress and time and the dependence of Beta on the statistical distribution function of the parameter of interest as well as the effect of the definition of failure used. This is illustrated by some empirical results in an idealized model as well as some actual test results achieved on semiconductors.

The preceding results are used to relate various kinds of Weibull behaviour to the real physical domain. The effects of several kinds of failure processes are shown to have different kinds of Weibull behaviour. The effects of different statistical distributions are illustrated as well as the effect of operations such as sorting and truncation.

A unique derivation of a "mixed" Weibull process is given and an idealized model for a "perfect" Weibull is demonstrated. (Author)

REVIEW: It is unfortunate that this paper and some others in the Transactions of the Eighteenth Annual ASQC Convention were merely abstracted and not published in full. Perhaps in such cases the authors can supply copies of the full text to those who may request them.

From the description, it would appear that the full text of this paper includes some useful features, which would serve to supplement other published work on the Weibull distribution and various aspects of its role in reliability analysis. These include the papers covered by Abstracts and Reviews Serial Numbers 320, 437, 499, 749, 751, 801, 848, 1015, 1171, 1435, 1453, and 1473. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1539
Codes 320;812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A shipbuilder's contribution to Bureau of Ships quality/reliability training

AUTHORS: O. R. Goode and P. Mali, General Dynamics/Electric Boat, Groton, Connecticut

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, p. 301

PURPOSE: To summarize a quality/reliability training program.

ABSTRACT: The performance of shipyard personnel who define, design, procure, manufacture, assemble, test, and repair ships' systems and components is inherently variable because of shortages and inequalities in skills, knowledge, aptitudes, education and training. This performance variability can affect the quality of naval ships and their equipment. Consequently, training is a "must" in the shipbuilding industry. It provides an effective channel to further the understanding of performance variability and provides knowledge and information on the causes and possible remedies.

A training program which was developed had the following four overlapping phases:

1. Search and Research Phase - needs determination, research directives, gather data on defects, case histories and lessons to be learned, review state of the art, experience of shipbuilders and naval facilities, BUSHIPS Management, and Quality/Reliability reports.
2. Development and Design Phase - Screening and evaluating, subject matter, training manual, schedule, lesson plans, training aids, mock sessions and audits, and BUSHIPS approval.
3. Learning Phase - Lectures/questions, conferences, case analysis, discussions, workshop, films, tour, teaching machines.
4. Evaluation Phase - Quizzes, written paper on quality assurance, BUSHIPS audit, lecturer's check, program manager's evaluation and student critique.

Five specific objectives were to be satisfied:

1. Quality/Reliability Assurance as a management function.
2. Attitudes and Communications in Quality Assurance.
3. Organizing for Quality Assurance.
4. Shipyard techniques and methods in Quality Assurance.
5. Quality Assurance Audit and improvement. (Authors in part)

REVIEW: While the paper is quite brief, it may have interest for those actively engaged in such training programs. It is not tutorial, and gives no details on the implementation of the ideas presented. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1540
Codes 300;800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The key to product reliability

AUTHOR: Sidney Price, Burroughs Corporation, Electrodata Division, 460 Sierra Madre Villa, Pasadena, California

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, p. 302

PURPOSE: To cite the need for better attitudes toward quality on the part of everyone involved in the manufacturing process.

ABSTRACT: All groups within a plant must have a positive attitude toward building the product right the first time. This involves improved skills and attitudes. The improved attitudes are the key to better product reliability.

REVIEW: The author's comments are brief and appropriate. They are worth the thoughtful consideration of all who are in a position to implement them. The paper in the Transactions is essentially an abstract, but the complete text (7 pp.) is available from the author. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1541
Codes 815;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Standardizing parts reliability

AUTHOR: George R. Tallent, Motorola, Inc., Phoenix, Arizona

SOURCE: Transactions Eighteenth Annual Convention, American Society for Quality Control, Buffalo, New York, May, 1964, pp. 305-307

PURPOSE: To discuss the purchase specification of small-lot high-reliability parts.

ABSTRACT: The full treatment on manufacturing and purchasing parts which have very high reliability is very expensive compared to omitting the high-reliability requirement. On small orders, the cost and time are usually prohibitive. The best thing to do in that case is to pick a supplier who has been making high-reliability parts and to start with a device of known reliability. The manufacturer can then suggest an adequate screening program. Preconditioning screens may also be employed. Some life tests must be run, of course.

REVIEW: This is a common problem. Unfortunately the author comments indirectly on the standardizing aspects of parts reliability--thus the title is somewhat misleading. The suggestions appear to be worthwhile; in practice the problem is likely to be one of "to what degree should something be done?" ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1542 -1
Codes 716;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Research toward a physics of aging of silicon p-n junctions

AUTHORS: H. C. Gorton and K. P. Duchamp, Battelle Memorial Institute, Columbus, Ohio

SOURCE: IEEE Transactions on Component Parts, vol. CP-11, pp. 28-32, March, 1964

PURPOSE: To outline a physics of aging program based on a modified Eyring rate equation and to draw practical conclusions from the incomplete data gathered so far.

ABSTRACT: As part of the Electronic Component Reliability Center at Battelle Memorial Institute an experimental program has been initiated, the goal of which is to develop an approach to reliability prediction based on an understanding of the physical processes responsible for degradation of performance characteristics of electronic component parts. A modification of the Eyring rate equation, accounting for the effects of nonthermal as well as thermal stresses, is used as the mathematical model. The modified Eyring equation has the form

$$R = ATe^{-B/Kt}e^{(C+D/KT)S}$$

where T denotes temperature, K is Boltzmann's constant, S denotes the nonthermal stress and the constants A, B, C and D are to be determined.

Nominally identical devices are subjected to various levels of temperature and electric field (dc reverse bias across the p-n junction) and time rates of change of electrical parameters are determined. As sufficient data become available, the constants of the Eyring equation will be determined and its utility as a prediction mechanism will be evaluated.

The part type used in the experimental program is the ZJ 218-M silicon controlled avalanche rectifier, chosen because it is shaped so as to reduce the electric field strength at the intersection of the reverse-biased p-n junction with the surface. Insufficient data had been taken at the time this paper was written to permit a determination of the constants of the Eyring equation, but the following statements can be made:

1. Plots of reverse current versus reciprocal temperature yield activation energies that suggest that a copper impurity level controls the value of reverse current between -25° and 50°C.

2. The concentration of net ionized impurities, as deduced from measurements of junction capacitance as a function of reverse voltage, increases with time under thermal stress in the range between 150°C and 200°C, and decreases for thermal stressing at 220°C and above. Reverse bias is also applied during the stress

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

period but seems not to affect the results. (Authors in part)

REVIEW: This paper describes a specific "physics of failure" program, the goal of which is to establish laws of aging "which are just as basic to reliability as Newton's laws are to mechanics." The authors further conclude that "the Eyring model is a good candidate for the foundation of such a physics." The task of proving this conclusion and of achieving the stated goal is largely unfinished in this admittedly preliminary description of the program's accomplishments. A most interesting feature, however, is the demonstration of the general, non-reliability-centered information to be gained in the course of gathering data for fitting such a model. In this paper a portion of the available data is interpreted to yield meaningful results without the benefit of any statistics and actually provides answers to questions not necessarily the most directly related to the aging problems that initially gave rise to the investigation.

Several minor comments regarding the presentation of the data used to draw the second conclusion (as listed in the ABSTRACT, above) are the following.

1. From the information given in Table I and the accompanying text it is not clear which cell underwent what stress.

2. The relationship, if any, between the nonthermal stress S in the Eyring equation and the width of the space-charge region S is not explicitly stated. The additional use of the symbol S_{ij} to represent the secant seems to be an unwise choice of notation.

3. No explanation is offered for the interesting but probably unanticipated observations. ##

Serial Number 1543
Codes 220;222

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Lot quality assurance approach to acceptance sampling procedures

AUTHOR: J. A. Tischendorf, Bell Telephone Laboratories, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 238-250

PURPOSE: To discuss sampling plans from the viewpoint of the consumer's interest.

ABSTRACT: The discussion is limited to attribute testing. Single, double, multiple, and sequential tests are qualitatively compared with emphasis on LTPD (Lot Tolerance Percent Defective). The LTPD is usually the lowest quality a consumer wishes to accept. Sampling plans can be based on LTPD and have advantages over other bases. The concepts of risk and confidence are explained. The term "confidence" is not applicable to other than single sampling plans.

REVIEW: This is a good introductory discussion of sampling plans with special emphasis on consumer's risk and LTPD. For those who desire more complete information, 13 references are cited. It should be noted that when the consumer's risk is set at 40% (as in some recent recommendations), many of the comments in this paper may not apply. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Common sense in sampling

AUTHOR: Maurice Prendergast, Raytheon Company

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 251-262

PURPOSE: To suggest a practical set of sampling plans.

ABSTRACT: It is necessary in most specifications and purchase agreements to include a sampling plan and usually it is a military sampling plan. If the manufacturer tests and the consumer tests, there may be disagreements. These usually arise from variations in the measurement processes or in the sampling method. Since military plans allow some flexibility, either side can use the flexibility to its own advantage. This arises because the plans specify AQL (Acceptable Quality Level). Most buyers prefer plans which specify LTPD (Lot Tolerance Percent Defective) since it tends to give them more protection. It is important to realize that the buyer really does not know exactly what quality level he needs and that the sampling plan is only part of the checking system. (Not all defectives are caught and some faults are intermittent.)

Tables are provided which show sample size vs LTPD, AQL and acceptance number. Only six values of LTPD and AQL per decade are used since it is rarely possible to make any real distinctions finer than that. The AQL values are not exact, but they are close enough (within 10%). No acceptance number is higher than ten because of the feasibility requirement. For each LTPD there are six possible AQL's to choose from. The AQL value tells the seller what quality he has to supply and the LTPD value tells the buyer what is the worst quality he is likely to accept. (Quality as good as the AQL is accepted 95% of the time; quality as bad as the LTPD is rejected 90% of the time.) One advantage of the table and the plans included therein is that any plan to the left of an LTPD column will also guarantee that LTPD and any plan above an AQL row will also guarantee that AQL. Thus any material which passes a plan to the upper left is satisfactory to everyone and the plan may have a smaller sample size. If it does not pass the auxiliary plan, the rest of the sample must be taken and measured; the practical errors in the probabilities will be small.

REVIEW: The author has presented cogent arguments for his plan. The plan seems quite simple and, in terms of use, involves nothing that need upset anyone. It is difficult to see what arguments will be advanced against acceptance of such a procedure, but reasonable to predict that there will be some. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1545
Code 224

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Life test qualification plans for continuous production

AUTHOR: Charles Toye, Philco Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 275-279

PURPOSE: To present life test qualification plans for continuous production.

ABSTRACT: Sampling plans most commonly used for life testing in the semiconductor industry provide reliability assurance on a lot-to-lot basis. That is, each lot is accepted or rejected according to its own life test results.

As the need for reliability assurance increases, so does the cost of providing this assurance. For example, assume that a manufacturer produces a device which is controlled to a failure rate of 2 percent per 1000 hours. For this same product Customer A specifies a failure rate of 20 percent; Customer B, 10 percent; and Customer C, 5 percent. Under the provisions of Method B, MIL-S-19500B, the manufacturer would sample 18 units per lot for A, 65 units per lot for B, and 206 units per lot for C. The reliability which Customer A receives is the same as that for Customer C, yet it costs 17 times more for life testing to the latter's specification. Why is Customer C paying more? Because he is paying for assurance. Assurance that his failure rate does not exceed a specified level. He is not buying more reliability. Life testing cannot build in reliability.

The key point in the assumption is that the manufacturer has a controlled process. This implies that the manufacturing process is producing a uniform product to a specific reliability level.

Life test qualification plans based on sequential sampling are presented and briefly described. Their advantages are pointed out. (Author in part)

REVIEW: This appears to be, in effect, a companion paper to the one which follows it in the book (see Abstract and Review Serial Number 1546). For a complete understanding of what the author is suggesting one should really read the other paper first.

It might be noted that it is more common to continuously test for the existence of a controlled process than to assume categorically that it exists. Also, Customer C mentioned in the above ABSTRACT may in some instances be buying more reliability than Customer A --depending on what the true process average actually is. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1546
Codes 224;762

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Sequential methods used for process qualification

AUTHOR: Rodger Blackwell, Philco Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 280-291

PURPOSE: To describe a method of process qualification based on sequential analysis.

ABSTRACT: This paper deals with qualification or certification of semiconductors to specific failure rate (λ) values through the use of the method of sequential analysis. Although the use of sequential test procedures to determine lot acceptance is not particularly new, the use of the same philosophy for qualification of the process to failure rate values, through transistor life tests, is new. The basic mathematical formulas that govern sequential testing are reviewed as a basis for common understanding. The introduction of the usage of λ (failure rate) designations for different process average values is also defined.

Since the formulas for the sequential test procedures are rather cumbersome, a nomograph for use in their solution is included. (Author)

REVIEW: This is a clearly-written paper which accomplishes its purpose quite well. The basis of the new feature (see ABSTRACT) is that a failure rate value (based on 1000-hour life tests) is identified with the quantity usually designated as "fraction defective" in acceptance sampling. Until this becomes clear to the reader, he may wonder about the use of the symbol λ in the discussion of the sequential probability ratio.

The method would appear to have considerable potential value, and it would be useful to have some reports of its implementation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1547
Codes 222;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Use of Weibull sampling plans

AUTHOR: George J. Blakemore, ARINC Research Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 292-304

PURPOSE: To present some sampling plans based on the Weibull distribution.

ABSTRACT: The results of analyses performed on semiconductor life test data indicate, with increasing confidence, that the failure mode is one in which the failure rate decreases with time. Among other distributions upon which one might base sampling procedures that make use of a decreasing failure rate, the Weibull distribution is applicable.

This paper presents sampling plans which assure (1) a minimum mean life, (2) a maximum hazard rate at some specified life, and (3) a maximum failure rate that is the average over some specified interval of life.

For the life testing of semiconductor devices, it seems wise to apply sampling plans based on the Weibull distribution for selected values of the shape parameter β, since they make use of what appears to be the actual failure distribution. The generally used sampling plans based on the special case of the exponential distribution are included among the Weibull plans.

Nine references to pertinent literature are cited. (Author in part)

REVIEW: While the arithmetic of the plans was not checked in detail, this paper appears to present the sampling plans adequately. The graphs and tables are not very comprehensive, but serve to illustrate the procedures well. In these plans, the value of β is assumed to be known, a restriction that may well prove to be severe in practice. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1548
Codes 760;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Suppliers' responsibility for inspection

AUTHOR: Charles J. Brzezinski, Office of the Assistant Secretary of Defense (Installations and Logistics)

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 305-313

PURPOSE: To examine the effect of making the supplier contractually responsible for inspection.

ABSTRACT: The specification of inspection requirements in accordance with the DoD quality assurance concept and policy is a radical departure from the traditional quality assurance provisions. From the consumer's point of view, the new inspection requirements provide better assurance that product conforms to specification requirements. From the producer's point of view, the new inspection requirements permit the use of efficient and economical inspection procedures. (Author)

REVIEW: This paper deals with the difficulties involved rather than with specific sampling methods. It does discuss the differences between plans based on producer's risk and those based on consumer's risk. (The paper covered by Abstract and Review Serial Number 1544 discusses plans intended to remove some of the problems discussed here.) The comments on a realistic approach to in-process inspection as compared to final inspection are good. It is not clear whether the new provisions apply only to DoD or to all government agencies, nor how and when they are to be implemented.

While most government specifications require qualification and lot acceptance tests, they do not say explicitly who is responsible for these tests. The lot acceptance tests prescribed in the specification are often not the ones normally used by the item manufacturer. He will usually be following his own specifications, manufacturing and inspection procedures, with a view to selling according to many different customer specifications. Hence the lot acceptance tests are often not performed, depending on the integrity of the supplier and the knowledge of the government inspector. Some large-scale governmental action is appropriate, and the type of thing proposed in this paper seems reasonable. However, the overhauling of all specifications will take time. It would seem that there is a need for (1) appropriately prepared specifications and (2) some policy of incorporating an appropriate statement into the contract, with a provision for permitting the manufacturer to use his own lot acceptance test when it is so negotiated. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Verification of product acceptance inspection by attributes

AUTHOR: J. Mandelson, U. S. Army Chemical Corps Materiel Command

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 314-319

PURPOSE: To discuss the framework of DoD Handbook H109, 6 May 1960.

ABSTRACT: The main purpose of the verification is not to check the product, but to check the supplier's method of inspection. The procedure is actually carried out by making a small inspection to see if the same results are obtained. The chance of rejecting falsely the supplier's inspection methods is 5% on a lot-by-lot basis. Further tables are included in DoD Handbook H109 for a cumulative validation by combining results from many samples. This is, of course, a more sensitive test. The chances of falsely accusing the supplier are kept to 5% and 1%, depending on the action to be taken. DoD Handbook H109 contains operating characteristic curves for showing these probabilities.

REVIEW: This is not a description of the tests, but a discussion of the principles involved. The point can be a tricky one, but appears to be well handled in this paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Achievement of high reliability levels for Minuteman solid state devices

AUTHOR: W. J. West, Autonetics, A Division of North American Aviation, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 322-334

PURPOSE: To describe reliability improvement programs of suppliers of semiconductor devices for the Minuteman program.

ABSTRACT: Reliability requirements for prelaunch and flight periods of each major subsystem supplied for the Minuteman program were developed, based on trade-off studies between warhead size, accuracy, tactical requirements, and costs. The results of the system requirement study established a reliability requirement for improvements of several orders of magnitude in the reliability of electronic systems.

Some of the system design and fabrication techniques used for reliability improvement are discussed in order to better explain the parts reliability requirements. Mechanization studies led to such decisions as: (1) no relays, (2) no variable resistors, (3) silicon diffused-type semiconductors where possible, (4) digital circuitry where possible, and (5) hermetically sealed and cooled electronic packaging. Each item in the system was budgeted a quantitative reliability requirement, and predictions were made by adding failure rates. Failures caused by drift of part parameters were accounted for by applying such recently-developed techniques as worst-case analysis, circuit variation studies, and Monte Carlo methods. The parameter stability problem is included as one of the objectives in the parts reliability improvement program.

Additional effort was needed above the design and fabrication measures to achieve the system reliability requirement. A research and development type of parts reliability program was implemented. A first step was to stabilize the output of the supplier's production line. Failure modes were then identified, and methods of correcting them incorporated. A matrix of tests at different conditions were performed to evaluate program progress. Examples of failure analysis and corrective action are given. Test results are discussed for a specific transistor and diode.

REVIEW: The program described in this paper was a milestone in reliability programs in the government-contractor environment. Both the parts reliability improvement and the design and fabrication approaches were actual and full implementations of what many others were only talking about. This paper is nicely organized and well

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

illustrated, and will make particularly interesting reading for and serve as motivation to those persons who have been trying to promote the acceptance of organized reliability activity. Additional reports on actual achievements of the system prelaunch and flight reliability and a system effectiveness analysis would be of wide interest.

The paper fails to note the scope of the program in terms of the extent of its applicability within the Minuteman system. Also, no references are cited for additional information on the many facets of the complete program which are mentioned in the paper.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Tomorrow's reliable semiconductor specification

AUTHOR: Vern K. Erickson, Minneapolis-Honeywell Regulator Company

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 335-366

PURPOSE: To present the results of a task group study to attempt to satisfy a need for specifying reliable semiconductor devices.

ABSTRACT: The Joint Electron Device Engineering Council (JEDEC) Semiconductor Device Reliability Specification Task Group as a first effort attempted to measure the reliability state-of-art from both manufacturers and users by means of a questionnaire. This yielded an extreme divergence of answers. A regimen, or philosophy evolved from the questionnaire results and other studies. This regimen was to serve as a basis for device specifications, and it is outlined below.

1. Reliability assurance of devices for general applicability can best be achieved through stress tests for controlling primary failure mechanisms.
2. It is feasible to specify several levels of reliability assurance for a given type of device.
3. It is reasonable to state anticipated maximum failure rates, even though they are too costly to assure.
4. Economic determination of high reliability to a high confidence level can be achieved through data accumulation from continuous production of a homogeneous product.
5. At present, diversity of failure mechanisms exists.
6. A graded acceptance concept should be used to provide for different reliability levels.
7. A group of devices has an inherent degree of reliability.
8. High reliability is best achieved when a homogeneous product is produced continuously in high volume.
9. There is a need for different approaches to the assurance of high reliability for applications requiring very low failure rates as opposed to those requiring long life.
10. Because of the diversity of application conditions, it is not possible to use a "typical" test to assure reliability for all applications.
11. Users have need for information on variations of device characteristics.
12. Failure distributions and acceleration factors should not be stated unless they are supported by test data.

An example device specification based on MIL-S-19500, Revision C is presented to illustrate an implementation of the above regimen. A guide for the preparation of other specifications in this format is included.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: The rationale presented in this paper contains approaches for improved control of the reliability of semiconductor devices to be effected through specifications. Some of the approaches offer needed improvements which should be capable of implementation. For example, data accumulation for qualification purposes (item 4 of the regimen) could help to eliminate the situation in which the qualification tests have not actually been performed. Also, greater utilization of data generated for purposes of specification compliance (item 11) could decrease expenditures made by device users to obtain the same data. Some illustration that the results of this study are not the ultimate, as noted in the paper, is contained within the twelve-point rationale. The wide variability of failure mechanisms noted in item 5 represents a difficulty in implementing the concept of assurance by controlling failure mechanisms as proposed in item 1. Another example is the fact that the diversity of failure distributions implied in item 12 leads one to question the meaning of the failure rates proposed in item 3.

The results of the task group activity are well presented in this paper. It is rather long and could have been shortened somewhat by the omission of Appendix I, which is duplication of material previously presented. References on actual task group report(s) are omitted. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1552
Codes 815;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Semiconductor specifications for ultimate reliability

AUTHORS: H. R. Widditsch and C. S. Bartholomew, The Boeing Company

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 367-380

PURPOSE: To develop the theme that present system reliability requirements can be achieved through adequate manufacturing controls, part screening techniques, and application disciplines.

ABSTRACT: The need for a two orders of magnitude improvement in semiconductor failure rates is illustrated by several examples. Emphasis on failure rate demonstration should be shifted to failure mode elimination and reliability assurance. The proposed attack for device manufacturing control is to require the part supplier to document and implement a reliability assurance program. This entails emphasis on the typical areas of quality control. The number of substandard devices can be reduced through the use of such techniques as meticulous inspection, continuous limits for electrical characteristics, and screening. Misapplications of parts are to be minimized by obtaining and disseminating information on drift of device characteristics and stress reduction. Some changes in part specifications are presented which will provide an adequate basis for procurement of parts having high reliability levels.

REVIEW: This is a loosely developed paper which covers a wide scope of reliability measures in a general manner. The types of measures presented are certainly applicable to the achievement of ultimate reliability levels of parts. It is not clear to whom the paper is addressed or how it is to be implemented. The typical supplier of equipment to the government cannot implement an ultimate reliability approach unless the procuring agency so desires. The extent of applicability of such ultimate reliability philosophies to specific programs is collectively controlled by governmental agencies. The extent to which it is cost effective to generally apply ultimate reliability approaches is not developed in this paper.

An error exists in the formula on page 371 in the paper. Instead of

$$P(F) = P(O)P(E) + \{1 - P(O)P(E)\}P(D)$$

it should be

$$P(F) = P(O)P(E) + \{1 - P(O)\}P(D),$$

where all symbols are defined on page 371. The error is due to the inclusion of a term representing the probability that a defective part is detected but is subsequently used in an inadequate design. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1553
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability assurance in semiconductor specifications

AUTHORS: B. W. Merkle and W. L. Blose, International Business Machines Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 381-392

PURPOSE: To discuss the requirements placed on components by the device procurement specifications for a highly reliable missile system, including some desirable future specifications.

ABSTRACT: Quality assurance provisions included in device procurement specifications are discussed under the following headings: (1) electrical parameters, (2) in-process environmental tests, (3) in-process life tests, (4) failure analysis, and (5) vendor surveillance. Certain electrical parameters can give a buyer a degree of confidence that a given lot is reasonably reliable. Those discussed include leakage currents, breakdown "jitter", and parameter sensitivity to temperature cycling. It is emphasized that electrical parameters specified for quality assurance are not necessarily the same as those which determine satisfactory system performance. A qualitative analysis of the vendor process control is monitored during lot fabrication using a lot-by-lot in-process environmental test and a life test, both on a small-sample basis. All failures occurring in these tests are forwarded to the purchaser's facility for analysis prior to a decision concerning the disposition of the lot. A vendor surveillance clause is included, to assist in the evaluation of the process control. The concept of burn-in testing is discussed.

REVIEW: The specification approach described in this paper appears to be a compromise between an ultimate reliability effort, with its associated high costs, and a routine assurance program. In this type of effort one is selecting from among various possible approaches, all of which tend to be qualitative, and the decision is difficult. The measures described are reasonable for this type of situation; whether or not they are optimum cannot be stated. For example, qualification testing is not discussed and presumably was not specifically required. For the success of any approach, it is most important that there be a clear understanding between the vendor and the purchaser as to the details of implementing the specification. It is not clear from the paper just where the present specification or future specification is being discussed. Better reader's perspective would have been aided by additional remarks on such background factors as the extent of specification use and the role of the purchaser's internal parts engineering and quality efforts. Some remarks on the actual results of the approach would also be of interest. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1554
Codes 815;840

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Guide for specifying the reliability of semiconductor devices

AUTHOR: W. P. Cole, Philco Corporation

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 393-400

PURPOSE: To discuss a guide for providing a uniform means for generating and presenting data in a manner which will indicate the reliability of semiconductor devices at various stress levels.

ABSTRACT: A guide for specifying the reliability of semiconductor devices has been prepared by the Electronic Industries Association Subcommittee M-6.2 on Reliability Criteria of Semiconductor Devices. It is primarily an engineering guide, but may be used as the basis of a device specification. The guide considers both degradation and catastrophic failures. Samples of the devices under consideration are to be life-tested by storage at different stress levels for acceleration, with temperature the primary stress considered. The guide recommends sample sizes for various confidence levels and failure rates, and presents a failure rate-temperature acceleration relationship. Electrical parameters to be recorded are suggested. The format for the presentation of variables data is a histogram of normalized degradation data at various times. Some graphical methods of monitoring failure rate versus time and temperature are presented.

REVIEW: The topic of this paper is important to the further development and application of reliability analysis techniques concerned with performance variation. Available mathematical, statistical, and empirical techniques for performance variation analysis are far ahead of the general availability of associated data. The paper loosely covers the generation and presentation of these reliability data. Although the relationship to specifications is not discussed in the paper, it appears reasonable and advantageous to develop this type of data in association with the testing required in specifications. Report(s) of the committee, which would be of interest to those concerned with the area, are not referenced.

The author, in a private communication, has forwarded a copy of a draft of the Guide which was distributed at the conference. It is entitled "A Guide for Specifying the Reliability of Semiconductor Devices, Part I: Storage Temperature Acceleration Methods", and was prepared by The Reliability Criteria of Semiconductor Devices (M-6.2) Subcommittee, Engineering Department, Military Products Division, Electronic Industries Association (no date given). Topics which are discussed in the paper are fully presented in the Guide. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1555
Codes 844

810;833

770;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effective degradation screen for detecting potentially unreliable silicon transistors

AUTHORS: Albert Fox and G. J. Hahn, General Electric Company

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 100-105

This is a preliminary report on the development of a degradation screen for detecting potentially unreliable silicon transistors. A later and more comprehensive report on the same program was covered by Abstract and Review Serial Number 982.

TITLE: Derating philosophy on Minuteman transistors

AUTHOR: G. K. Cullers, Autonetics, A Division of North American Aviation, Inc.

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 130-138

This paper is essentially the same as the one covered by Abstract and Review Serial Number 176.

TITLE: Measuring dynamic characteristics of semiconductors for reliable circuit design

AUTHOR: F. J. Potter, General Dynamics/Telecommunication (now with General Electric company)

SOURCE: Semiconductor Reliability Volume 2, edited by William H. von Alven, Engineering Publishers, Elizabeth, New Jersey, 1962, pp. 162-180

This paper is the same as the one covered by Abstract and Review Serial Number 584. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Is the relay going the way of the dodo bird?

AUTHOR: W. A. Murray, The Boeing Company, Aero-Space Division, Seattle, Washington

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 1-1--1-10

PURPOSE: To discuss the ability of the relay to compete effectively with semiconductors.

ABSTRACT: If relays are to compete effectively with semiconductors, steps must be taken to improve relay reliability. The semiconductor industry has developed techniques to improve the design, production, and application data of its devices; the relay manufacturer should learn to do the same.

It is maintained that relays have several advantages to offer over semiconductors. The cost of a system using relays is generally much lower than for a semiconductor circuit. Current and voltage switching capabilities of relays are generally much higher. Relays are capable of isolating the input from the output circuit and are capable of switching between two mutually isolated circuits. Relays are more tolerant of transient voltage conditions and are less susceptible to damage by nuclear radiation.

In many instances the manufacturers of military systems have been reluctant to use relays because of the lack of application data, the inability to predict relay reliability, and the frequent lack of process and quality control during manufacture. It is believed that the "people problem" is probably the biggest contributor to relay unreliability and a system of rigid controls is suggested which would reduce the chance of human error during manufacture.

The conclusions reached are that, in order to compete effectively with the semiconductor industry, relay manufacturers should take the following action:

1. Provide adequate application data to enable the user to properly apply the relay.
2. Provide data that enable realistic prediction of relay failure rate.
3. Institute rigid process and quality control procedures to provide relays of uniform quality.
4. Improve designs and manufacturing processes to minimize human errors in relay manufacture.
5. By means of tests and failure analysis, obtain a better

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

understanding of failure mechanisms which will be used to provide application data and to improve designs and processes.

REVIEW: Constructive criticism of the type given in this paper should always be welcomed by any industry--the relay industry would appear to have greater need for it than many. The paper will appeal most to those engaged directly or indirectly in the manufacture of relays. (See also Abstract and Review Serial Number 1565.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1557
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Matter transfer in contacts and the microscopic molten metal bridge

AUTHOR: Frank Llewellyn Jones, University of Wales, Swansea, U. K.

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 3-1--3-12

PURPOSE: To discuss the mechanism of matter transfer in light-duty relay contacts.

ABSTRACT: The main cause of failure of light-duty contacts is the erosion of electrodes and the progressive transfer of material from one electrode to the other. The use of the lowest practical voltages and series inductances has failed to eliminate this erosion or transfer, which is increased when the inductance or the voltage is increased. It is considered that there are two types of transfer. One type is associated with the occurrence of electrical discharges during the contact operation, and is evident when the circuit contains significant inductance, while the other type is a residium, obtained when the inductance is small and is independent of local circuit inductance. The first type is known as arc transfer and the other as fine, or bridge, transfer.

The fundamental physical processes which lead to these two types of transfer are discussed in detail. Recent experimental data on bridge transfer, including the results of measurements of transfer using radio-tracer techniques, are presented.

REVIEW: This is an excellent physics paper. The discussion of the transfer mechanisms makes interesting reading and has a direct bearing on the reliability of relay contacts.

The author in a private communication has suggested the addition of the following remarks regarding the experimental data reported and the final conclusions. "The metal transferred in an opening contact depends on the mechanism of rupture of the molten metal bridge. Forces concerned with bridge stability are discussed in the paper together with the results of rupture voltages and transfer measurements carried out in controlled atmospheres as well as *in vacuo*. Results are consistent with the picture that, while the bridge plays a part, with pure metals, the mechanism of transfer depends less on the properties of the stable bridge than on the discharge processes in the plasma produced after exploding. This plasma can have only a short life, but photographs indicate a lifetime of the order of 10^{-4} sec." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1558
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contact headaches--why have them?

AUTHOR: C. B. Gwyn, Jr., Gibson Electric Company, A Subsidiary of Talon, Inc., Delmont, Pennsylvania

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 11-1--11-31

PURPOSE: To discuss problems affecting the use of relay contacts.

ABSTRACT: The problems affecting the use of relay contacts are discussed under the following headings:

1. So--"What's Your Contact Problem?"
2. How To Be Within 3/64" to 3/8" Of Success And Still Have Your Relays Fail?"
3. "Ironically Your Present And Next Contact Problem May Have Already Been Solved."
4. "What Do You Expect From A Contact Material?"
5. "What You Should Actually Expect From A Contact Material."
6. "What's New And/Or Now Available In Contact Materials?"
7. "What's The Best Assembly Method For My Particular Contact Application?"
8. "All Contacts Are Vulnerable - What Affects Them And What Protects Them?"
9. "Hand Rules Of Thumb For Contact User Usage." (Author in part)

REVIEW: Many readers will find the familiarity of the style in this paper somewhat disconcerting. Otherwise it is an excellent paper which will prove useful to everyone with an interest in electrical contacts. The discussion of reliability is implicit in that any kind of contact problem will eventually affect relay reliability. ##

Serial Number 1559
Codes 782;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluation and control of residual moisture in hermetic relays

AUTHOR: R. A. Holcomb, Specialty Control Department, General Electric Company, Waynesboro, Virginia

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 14-1--14-5

PURPOSE: To discuss the effect of moisture on the operation of hermetic relays.

ABSTRACT: Residual moisture failures in hermetic relays show up in several ways such as (1) by the formation of ice on contacts, (2) by changing the dielectric properties of insulations, and (3) through chemical activity in corrosion cells. Detection of residual moisture in completed relays can be effected by tests based on one of the following two fundamentals: (1) the measurement of changes in insulation resistance as a function of internal relative humidity, and (2) the measurement of contact resistance following a thermal cycle designed to deposit ice on the contacts.

The following conclusions are reached: (1) specific relay types, such as those with their contacts mounted on the header, are quite sensitive to icing failures; (2) relays can pick up dangerous amounts of moisture in short periods of time when exposed to high humidities with the seal-off hole open; (3) laboratory tests for moisture, such as those described in the paper, are much more discriminating than temperature cycling tests on relays or equipment; (4) coils are the primary adsorption site for moisture with tremendous capacity compared to the relay parts; (5) existing relay moisture tests by themselves do not assure complete freedom from moisture failures in equipment; and (6) the best way to avoid moisture problems is to manufacture and use only moisture-free relays. It is recommended that equipment designers recognize the possibility of moisture problems in low-temperature applications and choose components accordingly. Moisture problems should be eliminated by proper control of moisture during manufacture of low temperature relays, rather than by extensive testing.

REVIEW: This is a good paper; the material is presented clearly and concisely. The possibility of contact icing as a factor in relay failure is interesting. One wonders how many unidentified intermittent faults have been caused by this particular failure mode. The method of selective condensation of water vapor used to test for contact icing described in the second test in the text is very ingenious. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1560
Codes 833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some considerations of the design criteria of the spark quenching circuits

AUTHORS: S. Mitani and Y. Araki, Totsuka Works, Hitachi Ltd., Totsuka, Yokohama, Japan

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 15-1--15-7

PURPOSE: To discuss experiments on the use of spark quenching circuits with wire spring relay contacts.

ABSTRACT: An experimental investigation has been made on the use of electrical discharge suppressors for the protection of relay contacts in telephone exchange equipment. The factors considered in the experiment included the relay type, contact loading conditions, the atmosphere surrounding the contacts, and the number of make and break operations during the specified lifetime.

It is supposed that corrosion at electrical contacts is caused by the action of nitric acid formed in the electrical discharge. It was found that corrosion can be prevented by reducing the relative humidity of the air around the contacts to less than 65%, providing good ventilation, and using spark quenching circuits. In wire spring relays the load current should not exceed 0.25A and the capacitance in the spark quench should be larger than that determined by conventional design criteria.

REVIEW: Whatever technical value this paper might have had is obscured by the authors' difficulties with the English language. To cite one example, "It was also proved, from the experimental result, that the corrosion was avoided enough by mounting the quenching units even under the high humidity." Difficulties of this nature could have been avoided if the Conference Proceedings had been edited. The foreign author should not be expected to provide a polished final draft of his paper in what is, to him, a difficult and alien language. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1561
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Circuits and relays for equipment reliability

AUTHOR: Howard C. Roberts, 511 W. Washington Street, Urbana, Illinois

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 19-1--19-10

PURPOSE: To describe methods of obtaining equipment reliability by using relay circuitry.

ABSTRACT: In the operation of equipment it is assumed that troubles of one sort or another will occur sooner or later. Consequently, in addition to design for normal operation, it is recognized as necessary that good equipment design provide means for preventing damage when conditions become unfavorable, and also that means be provided for isolating and identifying difficulties when they do occur.

Equipment reliability is discussed under two main headings: (1) circuit design for reliable operation, and (2) protective and diagnostic devices. Under the first heading there is a brief discussion of fail-safe design, followed by examples of correct relay application in different circumstances. Under the second heading the topics discussed include operator reenforcement, self-diagnosis and self-treatment by industrial equipment, automatic checking, diagnostic and protective signals, operation signals, power outage protection, automatic power-supply monitoring, and fusing. Relevant circuits are indicated.

REVIEW: Although the level of this paper is quite elementary, it contains a great deal of useful information. It is recommended reading for the person who does not know much about relay capabilities but would like to know more (or even those who think they know it all, but do not). ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1562 -1
Codes 770;815;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Minimum current testing and studies

AUTHOR: Charles P. Nunn, Filtors, Incorporated, East Northport, New York

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 20-1--20-15

PURPOSE: To discuss the results of a long-term research and development program in "minimum current" relay contact operation.

ABSTRACT: Relays exhibit contact resistance variations which are caused by some form of contamination. Since the demands on modern relays are much greater than those on their predecessors, and since their operation must take place in smaller volumes and under all environmental extremes, contact contamination is more important than heretofore. The demands on contamination and material control are at the limit of present technology.

The results of a long-term research and development program on contact performance in the area of low level to heavy arcing are discussed. The basic premise of the program was to achieve a major breakthrough in contact contamination control with a view to the development of a family of relays which would exceed the goals of the military specifications in power, low level, and minimum current areas.

The intermediate switching area, of interest in the program, is defined as the 1 to 250 ma current range and the 1 to 30 volt range. A failure criterion for contact resistance of twice that of loop resistance of the relay was chosen. Loop resistance is defined as the resistance of the terminal pins, contact materials, weld junctions, and constriction resistance of the contacts.

The relevant military specifications are discussed in some detail. Particulars of the testing procedures are given and preliminary performance determinations are made for standard relays. In the section on theory of failure mechanisms some of the current work in the field is reviewed. In a preliminary hypothesis it is assumed that contact resistance variations in the intermediate region of operation are due to organic contamination.

Three laboratory techniques are described which were developed as aids in determining the sources of contact contamination. By the use of these it was possible to pinpoint the major sources of contamination which were grouped into the following categories: organic materials, inorganic materials, vacuum de-gassing equipment, and sealing operations.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Two major innovations were made: the use of chromium diffused iron parts which reduced wear and flaking to indiscernable levels on bearing and impacting surfaces; the employment of ruby actuators in place of standard borosilicate actuators. These modifications made it possible for the relay to maintain stable electrical characteristics well beyond the three-million-cycle region, and wear particles were reduced to an insignificant number.

REVIEW: This is an excellent paper which will be of great interest to the relay design engineer. There is still hope for the relay as a reliable systems component if more programs of this quality are undertaken. More than one reading will be required in order to do justice to the paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1563
Codes 835;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relay microminiaturization and its effects on reliability

AUTHOR: R. M. Adkins, Union Switch & Signal, Division of Westinghouse Air Brake Company, Pittsburgh 18, Pennsylvania

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 22-1--22-16

PURPOSE: To discuss the effects of miniaturization on the reliability of relays.

ABSTRACT: It is maintained that relay miniaturization has been, and will continue to be, based on the following three factors.

1. Decentralization. This represents the trend brought about by improved methods of circuit assembly requiring several relays with fewer contacts located remotely, rather than a single relay with many contacts on a central location.
2. Use of Improved Materials. Use of materials with higher ratings will permit the relay designer to miniaturize further since these materials will perform equally well under greater stress.
3. Improvements in Associated Elements. As the circuitry and the circuit elements associated with relay applications are improved, the initially high ratings required can be reduced.

Simple formulas, based on the above three factors, are given for the following: contact resistance, contact bounce, armature rebound, operate time, coil life, shock immunity, vibration immunity, and contact life.

The influence of the three factors enumerated above is demonstrated, with reference to the derived formulas, by means of several practical examples.

REVIEW: The author has given a useful discussion of the effects of miniaturization on the performance of relays. The content appears to be aimed at relay designers and informed users. There is some slight confusion in the paper resulting from the misuse of the summation sign (Σ), and through the use of alpha (α) for a magnetic parameter and also as a proportionality symbol. However, these oversights do not invalidate the results.

Miniaturization, of course, has caused some serious relay problems. But, as the author concludes, with proper attention to design, manufacturing, and application considerations, the reliability of a miniaturized unit may actually be greater than that of an original larger unit. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1564
Codes 711;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relay reliability through spring stability

AUTHOR: Morris D. Scott, The Beryllium Corporation, Reading, Pennsylvania

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 23-1--23-2

PURPOSE: To describe the concept of metal "memory" as an explanation for creep.

ABSTRACT: The reliability of an electromagnetic relay depends upon both the electrical and the mechanical stability of its component parts. Mechanical failures can be grouped into the general categories of wear, mechanical hysteresis, fatigue, and creep or drift. Creep is defined as change in dimensions or shape under static or dynamic loading when the applied stresses are apparently less than the yield strength of the material. Consideration of this definition shows the inconsistency of expecting constant force from a spring which is changing shape or dimensions under the applied stresses of relay operation. Creep should be avoided in the materials used in relay springs.

Creep is explained by the concept of metal "memory": If a flat piece of metal is given a simple permanent bend it will "remember" its flat shape. A force which moves the spring back toward its original flat shape helps its memory, causing it to be unstable and to creep back to its flat shape. However, a force which moves the spring away from its original flat shape opposes its memory, causing it to be stable in operation. A sharp bend will be less prone to drift than one of generous radius. The ultimate in drift-free operation is achieved by the use of a material which can be heat-treated after all forming operations. Beryllium copper alloys are excellent for this use. This permits the replacement of an unfavorable memory (from the forming) by a favorable memory (from the heat treatment). Hand bending of a spring for any reason is unpredictable and undesirable; it should be avoided if at all possible.

REVIEW: The above abstract contains all of the useful information given in the original paper, which would have been improved by the addition of pertinent references. While the paper refers to relay springs, the concept applies also in other spring applications. Incidentally, another explanation of creep is that, in time, the material yields at strengths much lower than the short-time yield strength, even for virgin material. (It is hoped that the concept of metal "memory" does not lead to further work on the psychoanalysis of springs!)
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1565
Codes 770;815;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Relays--equipment expectations versus equipment performance

AUTHORS: J. K. Scott and J. J. McGorray, Westinghouse Electric Corporation, Surface Division, Baltimore, Maryland

SOURCE: Proceedings Twelfth Annual National Relay Conference, sponsored by National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma, April, 1964, pp. 24-1--24-6

PURPOSE: To discuss areas in which relay manufacturers do not meet relay specifications, or propagate literature subject to misinterpretation.

ABSTRACT: A relay test program at the Westinghouse Surface Division is described. In this program, tests on approximately 500 to 900 relays have been completed. The relays were divided into two generic groups: (1) 10-amp sealed power relay, and (2) 3 to 5-amp sealed telephone-type relay. The test used was based on MIL-R-5757C. Some nine vendors supplied 13 samples each of several items on the purchased part drawings. All relays were multi-pole, double-throw with standard coils. It was observed that a proportion of the relays supplied by vendors failed to meet specifications. For example, there was more than one instance in which vendors supplied two different relay types to meet a single specification; both were in the same type of can. In each instance one relay type could meet the electrical tests whereas the other could not. One problem common to all types and all vendors was found to be a very major one. Manufacturers' catalogues give contact ratings at 28VDC and 115 VAC. 120 VDC is also a common control voltage. A particular drawing specification called for contact ratings at 28 VDC, 115 VAC (60 cps) and 120 VDC with a temperature requirement of +85°C, and required 100,000 operations of life. It was found that the relays operated well for approximately 30,000 operations, but between 30,000 and 50,000 most of the units would explode. It was concluded that mixing of voltages in a sealed relay very definitely calls for a thorough investigation on the part of the relay industry and derating values applied to expected life.

REVIEW: This is a well documented account of relay manufacturers' failing to meet simple design specifications. Each year, at the National Relay Conference, there is at least one such paper. Occurrences of this type lead to the erroneous popular belief that all relays are inherently inferior to solid-state devices.

Relays have a definite part to play in modern systems; unfortunately, unless the guilty manufacturers upgrade their organizations, the relay will be as much a rarity as the steam locomotive. (The paper does not explain why the relays exploded.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: 12th Annual National Relay Conference Report

AUTHOR: (Editorial Matter)

SOURCE: Electromechanical Design, vol. 8, June, 1964, pp. 16-21

This is a summary of some of the more important and interesting papers presented at the Twelfth Annual National Relay Conference.

TITLE: Relay tests focus on contact performance

AUTHOR: F. J. Oliver, Editor

SOURCE: Electro-Technology, vol. 74, July, 1964, pp. 91-92, 94, 96-98

This is a summary of selected papers from the Twelfth Annual National Relay Conference.

The papers from this conference most likely to be of interest to reliability engineers have been covered by Abstracts and Reviews Serial Number 1556-1565. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1567
Codes 782;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Comments on "Heat-sinking techniques for power transistors in a space environment"

AUTHORS: D. F. Metz and R. A. Smith, RCA Astro-Electronics Division, Princeton, New Jersey

SOURCE: IEEE Transactions on Space Electronics and Telemetry, vol. SET-9, p. 138, December, 1963 (correspondence referring to the paper covered by Abstract and Review Serial Number 936)

PURPOSE: To point up a problem in a recommended heat sink procedure.

ABSTRACT: The use of indium and beryllium oxide in a heat sink may cause problems. The indium can cold flow and short out some terminals and the beryllium oxide is rather brittle and may crack. Each application should be analyzed for the results of these two effects.

REVIEW: The point is well taken by the authors that the risks of using such materials should be carefully weighed against their advantages.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Measuring and controlling property variability

AUTHOR: C. H. Hastings, Materials Department, Research and Advanced Development Division, Avco Corporation, Lowell, Massachusetts 01851

SOURCE: Materials in Design Engineering, vol. 60, July, 1964, pp. 84-85, 156 (adapted from Paper No. 64-MD-11, presented at the ASME Design Engineering Conference, Chicago, Illinois, May, 1964)

PURPOSE: To show that nondestructive testing provides a rapid and economical means for checking material and product variability.

ABSTRACT: Many failures are caused by the inability of a material to stand up under use conditions. Part of this problem is due to inadequately controlled variability in the properties of the materials. Many non-destructive "indirect" tests are available whose results can be correlated with those of destructive "direct" tests. Thus, preferably during the product development, tests for variability can be found which will prevent poor material from being used. Several examples are given.

REVIEW: The examples in this paper are interesting and the point that nondestructive testing provides a good means of checking variability is a valid (though not new) one. The author particularly emphasizes the use of nondestructive testing during the design and development phases so that product variability can be estimated from materials variability; corrective measures, if necessary or helpful, can easily be instituted at that time.

The first paragraph, which attempts to deal with failures in general, is inadequate because of the generality. For example, a separate cause of failure is a poor fabrication process, such as painting over a poorly prepared surface; one would hesitate to call a failure resulting from such a cause a material failure. Another example of too much generality is the implication that all failures are caused by a stress exceeding a strength; while the concept is useful in many cases, it is not universal--consider, for example, a pipe clogging with rust and shutting off the water flow.

Many engineers act as if they are unaware that the properties of materials vary from specimen to specimen; this article serves a valuable purpose in bringing this point forcibly to their attention. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1569
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electrical equipment reliability--application, design, or technology

AUTHOR: F. E. Kruse, Prestolite Division, The Eltra Corporation

SOURCE: 4 pp., presented at the National West Coast Meeting, Seattle, Washington, August 19-22, 1963, Society of Automotive Engineers paper 724A

PURPOSE: To review the progress which is being made in improving the reliability of the electrical equipment used with automotive and industrial internal combustion engines.

ABSTRACT: Reliability in engine electrical equipment can best be interpreted as the ability of the operator to start and run his engine without undue concern. Unreasonable reliability is expensive and wasteful. Reasonable reliability at a reasonable price for reasonable application is then the necessary approach. For extreme requirements, specialized equipment (generally available at extra cost) is warranted.

Assuming quality manufacture, reliability in equipment is achieved by: (1) tolerance to environment, (2) tolerance to use, (3) tolerance to abuse, (4) tolerance to lack of maintenance, (5) resistance to aging, and (6) proper application. Examples of recent technological improvements which tend to increase electrical equipment reliability include improved bonding techniques for protecting lead acid batteries from vibration damage, improved welded armature connections for diesel starter motors, improved mechanical design of the engagement mechanisms for starter motors, the use of alternators as the means of battery charging so as to make possible charging at both high and low engine speeds, the introduction of static regulators (expected to be reduced in cost quite rapidly), and the introduction of static devices to perform vital functions within ignition systems. In addition to the development of static systems for premium applications, improvements also have been made in the conventional automotive ignition system such that it is now possible to achieve operational reliability in excess of 20,000 miles on a properly matched and applied conventional system.

REVIEW: Although this paper, in title and organization, implies a discussion of the fundamental factors which affect electrical equipment reliability, it consists largely of statements of general truths which are, for the most part, self-evident to the engineering reader. The term "reliability" is used in its loosest sense, and often could be replaced by more accurately descriptive terms. This paper is probably of most interest to the semi-technical reader who is interested in technological trends concerning the electrical equipment used with internal combustion engines. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1570
Codes 711;775;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Dynamic crankcase stresses in visual color

AUTHORS: M. L. Kaesser, U. S. Army Engineer Research and Development Laboratories and H. N. Maier, Doehler-Jarvis Division, National Lead Company

SOURCE: 8 pp., presented at the National Farm, Construction and Industrial Machinery Meeting, Milwaukee, Wisconsin, September 9-12, 1963, Society of Automotive Engineers paper 735E (summarized in SAE Journal, vol. 71, October, 1963, p. 107)

PURPOSE: To describe the successful application of photoelastic methods of stress analysis to die cast aluminum crankcases of certain light-weight, air-cooled Military Standard Engines.

ABSTRACT: Photoelastic methods of stress analysis were applied to the die cast aluminum crankcases of 1.5- and 3-hp Military Standard Engines and the quantitative static and dynamic stress information thereby obtained made possible the design changes in the crankcases which make them considerably stronger and lighter. The photoelastic plastic used was initially in the form of a two-component liquid resin which, when properly mixed, was used to form sheets of carefully controlled thickness. While these sheets were still soft, i.e. before polymerization was complete, these sheets were contoured to shape directly on the crankcase, which had been cleaned to the bare metal and lightly coated with mineral oil. After contouring was completed and the plastic had become rigid, the plastic was secured to the crankcase with an aluminum colored reflective cement. Auxiliary forced air cooling was used during "hot engine" analysis to permit operation of the engine without cooling shrouding. Polarized stroboscopic light was used to permit observation of the dynamic strain distribution throughout the engine cycle. These photoelastic techniques yielded useful data on assembly, inertia, combustion, and thermal strains.

REVIEW: This paper is an effective presentation of the basic procedures used in the dynamic stress analysis by photoelastic techniques and of the considerable utility of this method of stress analysis. Particular emphasis is given to the application of the plastic, calibration of the plastic, the instrumentation which was used, and the interpretation of the results. Twenty-one illustrations are used to good advantage in describing procedures and results. As pointed out by the authors, photoelastic stress measurement techniques have two major limitations: the plastic cannot be used above 350-500°F and the area to be analyzed must be accessible to light. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1571
Code 824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Progressively censored samples in life testing

AUTHOR: A. Clifford Cohen, Jr., The University of Georgia

SOURCE: Technometrics, vol. 5, pp. 327-339, August, 1963

PURPOSE: To derive maximum likelihood estimators of the parameters of the normal and exponential distributions when samples are progressively censored.

ABSTRACT: In life and fatigue tests, individual observations are time ordered, and it is common practice to cease testing before all specimens under observation have failed. The resulting samples are accordingly censored on the right. In a typical case the test is terminated with a single stage of censoring, no further observations being recorded for any of the survivors. References to relevant work on single stage censoring are cited.

In many practical situations, the initial censoring results only in withdrawal of a portion of the survivors. Those which remain on test continue under observation until ultimate failure or until a subsequent stage of censoring is performed. For sufficiently large samples, censoring may be progressive through several stages. Such samples arise naturally when certain specimens must be withdrawn from a life test prior to failure for use as test objects in related experimentation. In other instances, progressively censored samples result from a compromise between the need for more rapid testing and the desire to include at least some extreme life spans in the sample data. When test facilities are limited and when prolonged tests are expensive, the early censoring of a substantial number of sample specimens frees facilities for other tests while specimens, which are allowed to continue on test until subsequent failure, permit observation of extreme sample values.

In this paper maximum likelihood estimators of the distribution parameters are derived for the normal and for the exponential distribution when samples are progressively censored. Two illustrative examples are given. (Author in part)

REVIEW: The mathematical results obtained in this paper have potential applicability in the type of test situation described in the second paragraph of the ABSTRACT, above. In typical reliability analysis problems, the results pertaining to the exponential distribution will be most commonly required. The material is clearly presented, and the author is careful to indicate the orientation of his results relative to those of other work in the area. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1572
Code 824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The sampling distribution of an estimate arising in life testing

AUTHOR: D. J. Bartholomew, University College of Wales, Aberystwyth

SOURCE: Technometrics, vol. 5, pp. 361-374, August, 1963

PURPOSE: To derive the exact sampling distribution of the maximum likelihood estimate of the parameter of the exponential distribution when the sample is time-censored, and to consider approximations to it.

ABSTRACT: In life testing it is often necessary to estimate the mean of an exponential distribution from censored data. This paper considers the problem as it occurs when each item in a life test is observed for a given period of time. If the item fails in this period its exact life is known, otherwise it is known only to exceed that period. The exact sampling distribution of the maximum likelihood estimate in this situation is obtained and used to show that the asymptotic sampling theory is inadequate unless the sample size is very large. An approximation to the distribution is proposed for use in small samples and compared with another method suggested in the literature. An alternative estimate is suggested which is both simple and highly efficient in certain circumstances. The methods are illustrated by examples. (Author in part)

REVIEW: Since time-censored data are of frequent occurrence in practical life-testing situations, the results obtained in this paper are important and useful. The material is clearly presented, relevant references are cited, and the examples serve to illustrate the application of the methods. It is useful to have a means of deciding when the asymptotic theory may be used, and to have methods of analysis suitable for small samples.

The author, in a private communication, has indicated that further comparisons of his approximation with the exact sampling distribution are contained in [1], which is as yet unpublished.

REFERENCE: [1] E. E. Bassett, "The estimation of the mean of the exponential distribution from censored data", University of Wales, 1964 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1573
Code 432

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effects of slow-downs and failure on stochastic service systems

AUTHOR: M. M. Eisen, International Business Machines Corporation, Thomas J. Watson Research Center, Yorktown Heights, New York

SOURCE: Technometrics, vol. 5, pp. 385-392, August, 1963

PURPOSE: To study the effects of slow-downs and break-downs on the mean queue length and waiting times in a stochastic service system.

ABSTRACT: The reliability and efficiency of a stochastic service system subject to break-downs and slow-downs is investigated. A mathematical model of such a system is a single server queue with Poisson input and exponential service time. However, the server is subject to break-downs and slow-downs, the lengths of which are exponentially distributed. During these periods he serves at varying rates. Analytic expressions are derived for the mean waiting time and the mean queue length. (Author)

REVIEW: This paper is the formulation and solution of a mathematical problem in queuing theory. As such, it will be of interest to the theorist rather than to the reliability engineer. The ideas have potential relevance to studies in maintainability/availability theory. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1574
Codes 822;872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: On the renewal function for the Weibull distribution

AUTHORS: W. L. Smith and M. R. Leadbetter, University of North Carolina and Research Triangle Institute

SOURCE: Technometrics, vol. 5, pp. 393-396, August, 1963

PURPOSE: To show that the renewal function associated with an arbitrary Weibull distribution can be expressed as an infinite series, the terms of which can be very easily computed by a straightforward recursive procedure.

ABSTRACT: The Weibull distribution has come to play an important role in various reliability studies. However, the calculation of the renewal function (which gives the expected number of renewals in any time interval) associated with this distribution is quite intractable. Renewal theory provides quite good approximations to the renewal function for reasonably large values of time. However, recent studies of equipment breakdown, in which the Weibull distribution appeared to be the appropriate one to take for intervals between renewals, required an evaluation of the renewal function for relatively small values of time. To overcome this difficulty, a series expansion is developed for the renewal function associated with the Weibull distribution. The expansion is valid for all values of the time t, and the coefficients of the powers of t are easily calculated numerically by a recursive procedure.

A typical situation in which this method is useful is that for which a lifetime distribution is being estimated through its hazard function, or conditional failure rate. If the graph of the logarithm of this estimated hazard function is fitted well by a straight line, a reasonable assumption is that the data follows a Weibull law and the Weibull parameters can be estimated from this graph. Changing the time scale if necessary so that the estimated distribution has the form cited in the paper, the recursive procedure may be applied to obtain the renewal function. (Authors in part)

REVIEW: This is an example of a mathematical solution to a problem of practical interest in reliability/maintainability analysis. The background and results are clearly and concisely presented. The brief remarks which are made regarding applications of the method are effective in making clear the type of problem to which it is applicable.

The paper contains the following two typographical errors: (1) the symbol $<$ should appear between the two fractions in expression (11), and (2) the denominator on the left hand side of inequality (12) should read $\Gamma(km+1)$. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1575 -1
Codes 774;823

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimation of the probability of defective failure from destructive tests

AUTHORS: A. C. Nelson, Jr., J. S. Williams*, and N. T. Fletcher**, Research Triangle Institute, Durham, North Carolina (*now at Colorado State University, FortCollins, Colorado; ** now at Florida State University, Tallahassee, Florida)

SOURCE: Technometrics, vol. 5, pp. 459-468, November, 1963

PURPOSE: To investigate the problem of estimating the probability that a defective item fails during field application under the assumption that the probability of failure is constant from trial to trial.

ABSTRACT: This paper compares four experimental procedures for estimating the probability p that a defective item fails in a field test. Let there be S defective items available for test and k pieces of test equipment. Assume that failure of an item during the test causes the loss of the testing equipment. Then it becomes necessary to limit the test to as few pieces of equipment as possible while obtaining an estimate of the proportion of defective failures, p, with the desired precision. The paper compares two estimators of the probability of a defective failure, namely, the maximum likelihood estimator and an unbiased estimator. The estimator to be used depends on the probability, p. The experimental procedure to be used is the one which uses as many pieces of test equipment as is economically possible and gives the desired precision of the estimate.

The problem is described in terms of shells, the manufactured item, and guns, the field support equipment. The following four experimental procedures are considered:

(1) Fire one shell from each of k guns ($S = k$).

(2) Fire k guns repeatedly until all guns fail or until a total of S shells are used by:

a) firing the first randomly selected gun until failure, then firing the second gun until failure, etc., until all S shells are used or until k guns fail,

b) firing each of k guns once, then firing a second time the guns that did not fail, etc., until all S shells are used or until k guns fail.

(3) Fire k guns repeatedly in random order as in (2)-b) until j guns fail, $j < k$, or until all S shells are used.

(4) Assign s shells at random to each of k guns ($S = sk$). Fire each gun until it fails or until s shells are used.

The maximum likelihood estimator and an unbiased estimator of the probability of a defective failure are compared for two of the four experimental plans. Graphs of the means, variances, and mean

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

square errors of the maximum likelihood estimator and the variance of the unbiased estimator are given for several values of k and for the case in which an infinitely large number of shells are available for tests. There is no clear preference for one estimator over the other, as the precision of the estimator depends on the probability of a defective failure. It appears evident that procedure (4), which gives equal weight a priori to all pieces of test equipment, is to be preferred. (Authors in part)

REVIEW: This paper is the formulation and solution of a rather specialized problem in statistical estimation. As such, it has little relevance to reliability analysis per se, except perhaps insofar as it illustrates an approach to the solution of a problem for which an appropriate "formula" is not available. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1576
Codes 551;553;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Tables for a precedence life test

AUTHOR: Lloyd S. Nelson, General Electric Lamp Division, Cleveland, Ohio

SOURCE: Technometrics, vol. 5, pp. 491-499, November, 1963

PURPOSE: To present tables for use in making a distribution-free, two-sample life test based on the order of early failures.

ABSTRACT: It is possible to test whether two samples come from the same population by counting the number (x) of observations in the sample yielding the smallest observation which precede the observation of r th rank in the other sample. This can be called a precedence test. It is mathematically equivalent to the exceedance test in which are counted the number (y) of observations in the sample yielding the first failure which exceed the observation of r th rank in the other sample. The tests are related by x = n - y for all r, where n is the size of the sample yielding the smallest observation. For life-testing, the precedence form of the test seems more natural and is easy for experimenters to grasp and apply. When, as is commonly done, it is assumed that the two populations under study are identical except for a possible difference in location, this test becomes a test for differences in averages ("slippage").

The literature on the exceedance test is reviewed briefly. Both one- and two-sided tests are considered. Tables are provided which cover all combinations of sample sizes up to twenty for one-sided (two-sided) significance levels of 0.05 (0.10), 0.025 (0.05), and 0.005 (0.01). An empirical approximation is given which yields critical values for any combination of sample sizes above five in the significance-level range of 0.005 to 0.10 (one-sided). The procedure is illustrated by worked examples. (Author in part)

REVIEW: This is a clearly-written paper which discusses the construction of the tables of critical values and gives numerical examples illustrating the type of problem to which the test can be applied.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1577
Codes 432;821;838;
872;882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Some waiting time distributions for redundant systems with repair

AUTHOR: Max Halperin, Sperry Rand Research Center, Sudbury, Massachusetts

SOURCE: Technometrics, vol. 6, pp. 27-40, February, 1964

PURPOSE: To investigate waiting time distributions between system failures for several models under the assumptions of exponential failure and repair laws.

ABSTRACT: In the design of systems with redundant components it is of major interest to have a quantitative measure of the relation between the number of redundant components and the reliability of the system. Various quantitative measures of reliability could be used but perhaps the most meaningful is the waiting time distribution between system failures. The relevance of such a distribution to a real system will, of course, depend on the extent to which our assumptions are an adequate description of the system, but even results obtained with simplifying assumptions should have considerable heuristic value. In specifying a system model there are many possibilities. For example, in addition to specifying a given redundancy, one may specify that components which fail are repaired. If one imposes this further specification, there are various assumptions one might make describing how repair takes place. Several possibilities are indicated.

Two types of system models are considered, designated as models A and B. For model A the following assumptions are made:

- A_1. The system is composed of N identical components, each independently following an exponential failure law with parameter λ.
- A_2. If a component fails it will be repaired and its repair time obeys an exponential law with parameter μ, irrespective of the number of components in failure.
- A_3. The system fails when, for the first time, n components are in failure, $1 \leq n \leq N$.

For model B the assumptions are the same except that the repair facility has finite capacity. Waiting time distributions between system failures are derived for models A and B. Generalizations to systems of k types of components are also considered. (Author in part)

REVIEW: This paper is a contribution to the mathematical theory of maintainability/availability. The orientation of the results obtained relative to those of previous work are indicated, and relevant references are cited. Perhaps the most important practical feature of this work is that it provides a means of assessing the gain achieved by the redundancy with repair model as compared to a model with redundancy and no repair. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1578
Codes 414;824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The discrimination between two Weibull processes

AUTHOR: A. S. Qureishi, Service Bureau Corporation, Palo Alto, California

SOURCE: Technometrics, vol. 6, pp. 57-75, February, 1964

PURPOSE: To solve the problem of selecting the one of two production processes with the larger mean life when units from the two processes fail in accordance with the Weibull distribution.

ABSTRACT: Given two production processes, the units from which fail in accordance with the Weibull distribution, the problem of selecting the particular process with the larger mean life is considered. Three techniques are discussed and three procedures are constructed to show their advantages. The three techniques are of the following types:

R_1. A nonsequential, non replacement type of procedure (where a decision has to be made after a certain predetermined number of failures, R ($\leq$ N, the initial sample size), are observed).

R_2. A nonsequential, replacement type of procedure (where a decision has to be made as in R_1, except that the failures will be immediately replaced by new items from the same process).

R_3. A sequential, replacement type of procedure (where a decision has to be made when a certain inequality regarding the differences between the numbers of failures from the two processes at a particular time is satisfied).

An alternative sequential procedure is also proposed and shown to be valuable in some situations. (Author in part)

REVIEW: As the author has indicated, this paper is a generalization of Sobel's work [1] on the exponential distribution, extending the results to cover the Weibull distribution. In view of the importance of the latter distribution in reliability analysis, this is an important contribution. The paper is extensive, detailed, and well-documented.

It might be observed that in practice mean life may not always be the parameter of most interest.

REFERENCE: [1] Sobel, Milton, 1956. Statistical techniques for reducing the experiment time in reliability studies, The Bell System Technical Journal, vol. 35, pp. 179-202. ##

Serial Number 1579
Code 824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Estimates of reliability for some distributions useful in life testing

AUTHOR: A. P. Basu, Bell Telephone Laboratories, Incorporated, Murray Hill, New Jersey (now at the University of Minnesota)

SOURCE: Technometrics, vol. 6, pp. 215-219, May, 1964

PURPOSE: To derive the minimum variance unbiased estimates of reliability for a number of distributions useful in life testing.

ABSTRACT: In the study of life testing and reliability analysis one important approach has been to consider an underlying 'life' distribution and to find suitable estimates of the parameters of that distribution. For practical reasons a relevant problem would be to get an unbiased estimate of reliability as otherwise, especially in complex systems, the cumulative effect of bias might be quite considerable and a system might prove unsatisfactory during 'operation time'.

In this paper the Rao-Blackwell and Lehmann-Scheffé theorems are used to derive the minimum variance unbiased estimates of reliability for the gamma, censored exponential, censored Weibull, and normal distributions. The orientation of the results relative to those obtained by others is indicated. Seven pertinent references are cited. (Author in part)

REVIEW: This paper is a contribution to the theory of estimation for certain distributions useful in life testing. It will be of specific interest to those concerned with minimum variance unbiased estimates of reliability. From a practical standpoint, it would have been worthwhile to illustrate the advantages which these estimates have over estimates possessing less attractive statistical properties.

The minimum variance unbiased estimate of reliability in the exponential case was derived in the paper covered by Abstract and Review Serial Number 1103. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1580
Codes 412;553;824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Exact confidence bounds, based on one order statistic, for the parameter of an exponential population

AUTHOR: H. Leon Harter, Aerospace Research Laboratories, Wright-Patterson Air Force Base

SOURCE: Technometrics, vol. 6, pp. 301-317, August, 1964

PURPOSE: To present tables for obtaining exact confidence bounds, based on one order statistic, for the parameter of an exponential population.

ABSTRACT: For a one-parameter negative exponential population, reasonably good interval estimates of the parameter σ may be obtained from one suitably chosen order statistic. The coefficients of the m th order statistic x_m in exact confidence bounds for σ are found by taking the negative reciprocals of the natural logarithms of percentage points of the Beta distribution. The interval between exact lower and upper confidence bounds, each associated with confidence 1 - P, is, of course, an exact central confidence interval (confidence 1 - 2P). Results have been computed for several values of m, clustered about the value which yields the most efficient point estimator, for sample size n = 1(1)20(2)40 and P = .0001, .0005, .001, .005, .01, .025, .05, .1(.1).5. The definition of efficiency commonly used for point estimators is extended to confidence bounds and confidence intervals. The following tables are included, together with a description of the method of computation and a brief discussion of possible uses: (1) a table of upper confidence bounds and central confidence intervals for σ, based on one order statistic, together with their efficiencies, for that value of m which maximizes the efficiency of the upper confidence bound, for each combination of n and 1 - P and (2) a similar table for that value of m which maximizes the efficiency of the central confidence interval, when the two values of m differ. A numerical example is also given. (Author)

REVIEW: This is a mathematical paper which, in addition to presenting the tables indicated in the ABSTRACT, gives also the underlying mathematical formulation and describes the method of computation. The tables will be useful in obtaining interval estimates for the mean time-to-failure, of items to which the exponential distribution is applicable, on the basis of incomplete life-test results (i.e., without waiting for all items in the sample to fail). The relative efficiencies presented in the paper are useful in this connection. Ten references to related literature are cited. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1581
Code 824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Application of the bivariate normal distribution to a stress vs strength problem in reliability analysis

AUTHORS: M. Lipow and R. L. Eidemiller, TRW Space Technology Laboratories

SOURCE: Technometrics, vol. 6, pp. 325-328, August, 1964

PURPOSE: To describe an application of the bivariate normal distribution to a stress vs. strength problem in reliability analysis.

ABSTRACT: In this note it is shown that $P(\eta - \xi > 0)$ can easily be calculated using tables of the bivariate normal distribution, where ξ, η are independent, ξ has a normal distribution, and η has a truncated normal distribution. This result has application to certain stress vs. strength problems in reliability analysis. Two related examples are presented. The related statistical problem, when the distribution parameters are not known but are estimated from data, is not considered.

The examples are concerned with the proof-pressure testing of solid propellant rocket motor cases. The result is used to determine the probability that the motor, when fired, will not fail because of case rupture. It is also demonstrated that it can be used to find an optimum level of pressure to use in the proof-pressure test in order to minimize total cost. (Authors in part)

REVIEW: The mathematical result in this paper is presented concisely, and the type of problem to which it is applicable is clearly illustrated. The user should note particularly that all four parameters of the two normal distributions must be considered known. This implies, essentially, that considerable data must exist on both the stress and strength distributions. (There is a typographical error in Equation (2) in the paper: the dividing line in the fraction preceding the exponential term is missing.)
###

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1582 -1
Codes 771;773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An approach to MTF testing

AUTHOR: Otto Altman, Lear Siegler Incorporated

SOURCE: The Journal of Environmental Sciences, vol. 7, April, 1964, pp. 13-15

PURPOSE: To describe an environmental test and its specially designed test equipment.

ABSTRACT: The concept of applying an inhouse test-established mean-time-to-failure (MTF) as a standard parameter for field performance measurement has been implemented by Lear Siegler, Inc. A series of closely-controlled tests has been developed to provide a true picture of equipment capabilities and endurance. Through the use of relatively inexpensive equipment, the total cost is kept well within limits without sacrificing quality.

This testing system was developed for the purpose of establishing a mean-time-to-failure value against which field performance could be measured for the Attitude and Heading Reference System of the Integrated Flight Panel on the F-105 fighter-bomber. To obtain a true indication of equipment reliability, a simultaneous combination of actual flight environments plus duplication of vehicle movements was necessary. A detailed plan was formed for a test to subject the equipment to temperature extremes and vibration, plus duplication of vehicle movements for the gyroscopic portion. Based on previous system testing experience, chambers were designed to contain components of two test systems. These were constructed of a 1-inch thick polyurethane sandwich material faced with aluminum. Vibration platforms were installed in the chambers but their driving mechanism and controls were mounted outside. Separate chambers were built for the gyros because of the added vehicle movement parameter. In addition, four chambers to contain the means for creating, receiving, and distributing the positive and negative temperature agents were constructed. Each distribution chamber was to service two of the systems under test and was connected to the equipment chambers by rubber hoses swathed in fiberglass.

Features of the equipment and its operation are described. Problems encountered and solved are cited. The applications and value of the data obtained are indicated. (Author in part)

REVIEW: This is a concise description of the implementation of a program for the testing of a specific system under the combined environments of temperature, vibration, and simulated aircraft movement. The basic premise on which such a program is based is that the effort put into reliability and maintainability of a system must

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

be considered part of its cost, and that better, more reliable systems "pay off" in the long run. This is a commendable point of view.

The area of combined environmental testing is one in which much work remains to be done. The problems become more difficult when the complex environment of outer space is considered, as compared to the environments encountered by conventional aircraft. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1583
Codes 715;770;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Testing of electronic components in a nuclear environment

AUTHORS: H. De Covnick and S. Nakazato, Aerojet-General Nucleonics

SOURCE: The Journal of Environmental Sciences, vol. 7, April, 1964, pp. 36-37

PURPOSE: To describe an irradiation experiment performed on a silicon-controlled rectifier using a low-power testing reactor.

ABSTRACT: Components of any space vehicle containing a nuclear reactor will be subjected to space and nuclear radiation. To meet reliability and design requirements, radiation effects data for the components used must be considered in the design. The radiation-sensitive components may be avoided or adequate shielding (at a premium) provided. An irradiation experiment was performed with two purposes: a) to demonstrate the effects of a nuclear radiation field upon a silicon-controlled rectifier (SCR) under electrical load, and b) to demonstrate the applicability and ease of performing an irradiation program at a low cost in the AGN-201P, a low power testing reactor.

The irradiation facility and the experiment are described briefly. The following conclusions are drawn:

1. The SCR characteristics change significantly after 10^{12} nvt.
2. Use of similar components in a radiation field requires radiation effects data.
3. Statistical testing should be performed to predict the behavior under radiation dosage.
4. The irradiation data from electronic components can be obtained simply and inexpensively in the AGN 201P. (Authors in part)

REVIEW: This paper is less general than the title tends to imply, since the experiment involved only the 2N1843 SCR. In addition, as the authors have pointed out, only two units were tested, so that no statistically significant conclusions can be drawn. Perhaps the major contribution of the paper is in pointing up and illustrating the advantages of the particular irradiation facility described. It would seem to have good possibilities as a convenient and relatively inexpensive means of obtaining data on the effects of a nuclear environment on electronic components. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1584
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Radiation damage to electrical material and components

AUTHOR: Lewis Epstein, Philco Western Development Laboratories

SOURCE: The Journal of Environmental Sciences, vol. 7, May, 1964, pp. 18-22

PURPOSE: To provide a bird's eye view of the most salient radiation damage considerations pertaining to space vehicles, together with several illustrative calculations.

ABSTRACT: The radiation energy dose absorbed by a component in a space vehicle may be deduced from a knowledge of (1) the radiation source, (2) the energy and kind of radiation, (3) the configuration and structure of the vehicle, and (4) the internal packaging of the components. In the spacecraft, permanent effects of the total dose absorbed are of the most importance. It is found, quite generally, that a component absorbs radiation up to some threshold without any appreciable effect. Beyond this critical dose, deterioration sets in. This behavior is depicted in the form of a graph of log of radiation effect vs. radiation energy absorbed by the component. Figures/graphs are also given for the following: radiation tolerance for various materials, silicon solar cell decay vs. one Mev electron dose, damage ratio between one Mev electrons and electrons of other energies, and damage ratio between protons and one Mev electrons. The last three figures in conjunction with a known energy spectrum and dose rate may be used to calculate a plot of degradation vs. time. Details of the calculations are given. Sample calculations are also given for radiation damage to non-photovoltaics and for the X-ray flux due to bremsstrahlung (stopping radiation).

REVIEW: This paper accomplishes the author's stated purpose of presenting a bird's eye view of the subject of elementary radiation damage calculations. For those who may wish to delve deeper, it would have been useful to give references, particularly pertaining to the sources of the graphs and figures. No background for the calculation procedures is cited either, but they will be reasonably clear to the person with a knowledge of the pertinent fundamental physics. The following two typographical errors were noted: on page 20 in the calculation of the effective atomic weight of sapphire, the symbol between the two terms should be + rather than =; the same is true in the corresponding calculation pertaining to glass on page 21. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1585 -1
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The nuclear radiation problem
Sources, environment and effects

AUTHORS: Sydney D. Black and Benjamin Bloch, General Precision Inc., Aerospace Group

SOURCE: The Journal of Environmental Sciences, vol. 7, May, 1964, pp. 23-29

PURPOSE: To describe radiation sources and environments, and their effects on electronic and electromechanical systems.

ABSTRACT: Designers of electronic and electromechanical systems are primarily concerned with radiation from such sources as a nuclear weapon burst, a nuclear propulsion system, nuclear power systems and solar, cosmic and magnetospheric radiation. In missiles and space vehicles, the weight penalty for shielding cannot be tolerated. This means that it is necessary to use equipment designed to operate in a high-radiation environment.

A nuclear detonation produces transient gamma radiation, transient neutron radiation, steady-state gamma radiation, steady-state neutron radiation and associated electromagnetic and electrostatic fields. The mechanisms involved in the production of this environment are described.

A nuclear propulsion system environment consists of continuous gamma and neutron radiation. The energy spectrum is similar to that of a fission spectrum. Over the life of the mission (which may last for hours or days or longer) the guidance system, etc. in the vehicle will be subjected to a large integrated gamma and neutron dose. Quantitive values of dosages will depend on the particular propulsion system and mission, but they will most likely be well (orders of magnitude) beyond the tolerances of today's components. The integrated dose environment is not unlike that of a nuclear weapon burst, though it is delivered over a much longer period.

There are three main sources of natural radiation, viz., cosmic rays, solar cosmic rays, and magnetosphere radiation. All three types consist primarily of charged particles. The first, cosmic rays, is of no concern insofar as radiation damage is concerned. Primary constituents of solar flares are protons and gamma rays. Peak intensities measured to date are of the same order of flux and energy content as the Van Allen belts. The magnetosphere (Van Allen belt) includes an inner belt composed mainly of protons with energies up to 4 or 5 mev per proton, and an outer belt composed mainly of electrons with energies in the range from 20 to 100 kev.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Neutrons can react with matter in two general ways, i.e. scattering type reactions and absorption reactions. Scattering reactions are divided into two general types, elastic scattering and inelastic scattering. The mechanisms of these reactions are briefly described. The gamma radiation produced by the detonation of a nuclear burst can interact with matter primarily in three types of effects: the photoelectric effect, Compton scattering and pair production. These effects are described in some detail in the order of increasing gamma radiation energy. Other topics which are considered in less detail are thermal energy effects, overpressure, and electrostatic and electromagnetic fields. (Authors in part)

REVIEW: This is a good concise description of radiation sources and environments and the general physical mechanisms of their effects. The latter are not interpreted relative to any specific components, although presumably the information given together with a knowledge of component structure would enable some inferences to be drawn.

No references are cited in this paper. However, there is a considerable volume of literature on the nuclear environment and its effects. Papers on this topic which have been covered by RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS are found under the codes 715 and 782.

A companion paper by the same authors covering the simulation and application of nuclear radiation is covered by Abstract and Review Serial Number 1588. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1586 -1
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Achievement of reliability in aerospace systems

AUTHOR: Bruno J. Forsher, General Dynamics/Pomona

SOURCE: The Journal of Environmental Sciences, vol. 7, June, 1964, pp. 9-13

PURPOSE: To discuss some of the current problems in achieving a satisfactory level of reliability in aerospace projects.

ABSTRACT: It is contended that reliability engineering for the advanced missile and spacecraft projects has remained largely ineffective. The following ten critical reliability areas are listed:

1. Lack of incentive.
2. Conflict with delivery schedule.
3. Lack of homogeneous data.
4. Lack of realistic quantitative measurement.
5. Lack of adequately defined contractual requirement.
6. Ambiguity in the system concept.
7. Absence of reliability control during research and development.
8. Reliability administrator qualifications.
9. Lack of understanding on the part of some contracting personnel.
10. The conceptual antithesis between research and reliability.

The order of importance of these areas varies from one project to another. Many accepted and beneficial reliability practices, such as design review and integrated environmental testing, lose much of their effectiveness because of the detrimental influences of these problem areas.

Incentive contracts are proposed as a means of inducing producers to direct more attention to effective testing, better integration of test activity, design reviews and corrective action, and essentially enhance the reliability engineering activity. Stipulations should be included to reduce the penalty of total delay of reimbursement when serious and compelling reasons cause a delay of hardware delivery.

The lack of homogeneous data and of realistic quantitative measurement points to a need for research in the following areas:

1. Development of authentic generic failure ratings based on sufficiently large sampling populations.
2. Influence of certain combined environments on the generic failure ratings.
3. Actual failure distribution and deviation from the (assumed) normal Gaussian curve.
4. Differences in failure count between singular environmental

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

stresses and combined environmental stresses.

5. Influence of the sequence of singular environmental stress testing on overall failure ratings.

6. Planning and coordination between environmental testing and flight testing.

In order to achieve reliability, all known tools must be applied wisely in a well coordinated and expertly integrated engineering-research-test effort. New tools must be formulated to assure planned reliability growth. Administration and management must assume their responsibilities together with reliability engineering to assure that every milestone (not just the last one) is reached as planned.

Then, and only then, will the gap between reliability potential and reliability achievement be narrowed to an acceptable one of reasonable tolerance and of error of judgment. (Author in part)

REVIEW: No doubt the problem areas cited by the author exist, to some degree, in many projects in which reliability is an important requirement. His suggestions for improvement are worthy of the thoughtful attention of all who may be in a position to implement or influence corrective action.

In the section on lack of homogeneous data the exponential reliability function is reproduced incorrectly: the minus sign in the exponent is missing. The assumptions on which the use of this function is based are rather unclearly and inaccurately stated, and could be misleading. In fact their inclusion contributes little to the mainstream of the discussion, since the use of any mathematical model will involve assumptions which will not be met ideally in practice.

The author, in a private communication, has indicated that the manuscript was drastically cut prior to publication, the most extensive reductions having been made in the section on lack of homogeneous data. He has commented further as follows: "The important point which I tried to make is that reliability data is by necessity tied to certain basic assumptions under which the data has been collected. Unless there exists good correlation between said assumptions and the actual conditions which may be experienced by an aerospace system, a reliability prediction for this system based on aforesaid data is probably erroneous." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1587 -1
Code 784

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Feasibility of simulating interplanetary space

AUTHORS: M. P. Hnilicka, Research Division, National Research Corporation, a subsidiary of Norton Company and K. A. Geiger, NRC Equipment Corporation, a subsidiary of National Research Corporation

SOURCE: The Journal of Environmental Sciences, vol. 7, June, 1964, pp. 28-33

PURPOSE: To describe the progress which has been made in the simulation of the space environment.

ABSTRACT: Simulation of space environment has three basic justifications:

1. Support development of engineering and technology to satisfy needs of astronautics
2. Secure reliability of spacecraft for required missions and train the crew
3. Furnish laboratory evidence for extraterrestrial theories

The support of engineering tasks and of novel design philosophies has been the primary purpose of the past generation of space simulators, represented by a large number of moderate size chambers in environmental laboratories.

Verification of applied designs and investigation of basic behavior of materials for new components has also been an important simulation function. Most of this work has been accomplished in small facilities. The effect of forces on gas-tight enclosures, evaluation of leakage from "canned" sub-assemblies, and problems of heat dissipation require moderate vacuum of 10^{-3} to 10^{-4} torr. Problems of surface physics, lubrication, wear, and studies of sliding and rolling friction, electric contacts and fatigue were made possible by advances in vacuum technology and pumping means to the level of 10^{-9} to 10^{-10} torr, and even lower. The state of the art is progressing; recently, a pressure level of 10^{-15} torr was achieved in an 80 liter, all-metal system.

Ensuring reliability of the orbiting vehicle or of a spacecraft in low altitude orbit requires testing at the system level at pressures 10^{-6} to 10^{-7} torr. The sizes of simulators must be larger to accomodate full-size spacecraft. This is the second generation of space simulators. Several units in sizes from 15 to 30 feet are currently in service. Construction of several 100-foot units is well advanced.

The first generation of laboratory size simulation of space offers capabilities for testing components and their functioning in a

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

routine fashion up to 700 km orbit altitudes.

The second generation of simulators of large size offers realistic simulation of solar thermal effect and by using LN_2 shield, cryo-arrays at $20^{o}K$, reasonable reliability testing of mechanisms of propulsion and mission support in lower orbit levels up to 700 km. Added areas of shielded cryoarrays cannot provide for valid reliability testing of mechanisms affected by surface effects of deep space. Upgraded concepts of simulation of interplanetary space is foreseeable for an improved generation of large simulators. These facilities will need chilling of containment walls to reduce gas loads from wall materials. The efficiency of capturing molecules on walls of the heat sink will need substantial improvement over present cryopumping arrays. Several promising concepts, using cryoadsorption techniques and offering nearly perfect accommodations, even of hydrogen molecules, are in the laboratory stage. Recently such techniques were used to reduce the pressure in an 80 liter system below the limit of presently available measuring means. Intensive development of these methods for large scale application is needed to bring interplanetary space simulation within the realm of economics.

Because feasibility of power generation by nuclear fusion depends on development of similar multimillion liters/sec. pumping capabilities to maintain molecular densities below 10^{-10} torr, joint effort of astronautics and nucleonics promises fast development of large-scale technology for interplanetary space simulation. (Authors)

REVIEW: This is a clearly-written and quite comprehensive account of the progress which has been made in simulating the thermal and low-pressure environments of interplanetary space. Problems encountered and solved are indicated, together with some of those which remain to be solved. This is clearly an area of importance in the reliability testing of space vehicles.

An aspect of the environment of outer space which this paper does not cover is that of nuclear radiation. In this connection see Abstract and Review Serial Number 1588. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1588 -1
Codes 715;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The nuclear radiation problem
Simulation and application

AUTHORS: Sydney Black and Benjamin Bloch, General Precision Inc., Aerospace Group

SOURCE: The Journal of Environmental Sciences, vol. 7, August, 1964, pp. 9-12

PURPOSE: To discuss the simulation and application of nuclear radiation.

ABSTRACT: The laboratory devices most commonly used for radiation effects testing can be divided into the following three categories: transient, steady state, and combined environment facilities. Transient facilities include pulse reactors, linear accelerators, and flash X-ray devices. Steady state reactors and gamma field producers are the most commonly used devices for providing steady-state radiation. Combined environment facilities attempt to simulate the weapon radiation environment. The available facilities in each of these categories are mentioned, together with their locations.

Each of the radiation facilities mentioned above has advantages and disadvantages in simulating a weapon environment. Pulse reactors produce a fission energy spectrum that is similar to that produced by a weapon, and permit the irradiation of a relatively large area. However, there is a marked difference in the widths of the pulses of the reactor and those of the weapon burst. Linear accelerators have a pulse width that is variable over a wide range, and the radiation is monoenergetic, but can be varied up to 45 mev on some devices. However, they cannot irradiate a large volume. The flash X-ray device is inexpensive, produces a gamma pulse whose width corresponds to that of a weapon burst during its peak, and can irradiate a volume of a few cubic feet. However, the flash X-ray device's pulse radiation is rather unlike that produced by a weapon blast. A steady state reactor provides a good simulation of the integrated neutron and gamma dose from a weapon burst, nuclear propulsion system, or nuclear power system. Continuous gamma radiation is produced by the decay of a radioactive material such as Cobalt-60. Because environments cannot be exactly simulated, and because of the uncertainties of measurement, it is difficult to correlate laboratory effects with measured fields.

It is important to determine what is known about the effects of radiation on electronics and what can be done to harden circuits to a radiation environment. Radiation effects of a nuclear explosion can be transient or permanent. These two classes are contrasted. Most of the work on which radiation data are available

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

has been done with steady state sources. The reasons for this are indicated. Much work in the identification of actual damage mechanisms remains to be done. Steps which can be taken to harden electronic circuits to the effects of nuclear radiation include (1) potting to reduce external ionization, (2) the use of low-impedance circuits, (3) the use of high trigger levels, (4) the adjustment of the frequency response of a system to obtain a long time constant, and (5) the use of more radiation-resistant components such as the field-effect transistor. The limitations and disadvantages of these steps are indicated.

REVIEW: This is a good brief description of laboratory radiation devices and their application in studying the nuclear radiation problem. As the authors have indicated, radiation effects on electronics is a field in which much remains to be done. This paper gives a good picture of what has been/is being done. Four pertinent references are cited for those who desire more details.

See Abstract and Review Serial Number 1585 for a companion paper by the same authors in which radiation sources, environments, and their effects are described. ##

Serial Number 1589
Codes 770;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Saturn reliability through environmental tests

AUTHOR: Cecil A. Brakebill, Chrysler Corporation Space Division

SOURCE: The Journal of Environmental Sciences, vol. 7, August, 1964, pp. 13-17

PURPOSE: To describe the Reliability Test Program for the Saturn S-IB Stage Booster.

ABSTRACT: The Reliability Test Program for the Saturn S-IB Stage Booster consists of a series of laboratory tests in which systems, assemblies and components are evaluated to establish their operational capabilities and reliability characteristics. The ultimate objectives of the test program are as follows: (1) to detect and isolate unreliable hardware and determine the nature of the unreliability, (2) to provide the necessary information for design changes to improve operational performance or increase reliability, (3) to supplement design analysis data with test data, (4) to establish, through retesting of hardware previously found unreliable, that modification has improved reliability to the required level, and (5) to measure, through life-cycle or test-to-failure methods, the reliability attained and to determine the confidence level of the results.

A screening analysis was conducted on vehicle hardware to determine critical components. The hardware was then tested under the most severe environments encountered in service -- flight loads, temperature, altitude, acceleration, vibration, shock, humidity, life-cycle, etc.

Tests were accomplished by selectively sequencing the environments to be performed on each piece of hardware and by using test-to-specified-level techniques. As it was not economical to provide a sufficient number of test samples for a comprehensive statistical evaluation of reliability, all tests were designed to yield maximum information. Data yield was optimized by employment of the following techniques: (1) conducting tests at system or assembly, as well as component level, (2) conducting tests in order of least probability of damage to the system, assembly or component, with environmental conditions applied at increased levels of severity until failure occurred, or until reliability was demonstrated, and (3) sequencing of environment to expose environmental interactions. (Author)

REVIEW: This is a clearly-written account of the salient features of the subject test program. As such, it should be of interest and value to those concerned with the initiation/implementation of test programs on other projects. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1590
Code 832

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability and quality assurance of man in a man-machine system

AUTHORS: T. M. Fraser and A. H. Schwichtenberg, The Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico

SOURCE: The Journal of Environmental Sciences, vol. 7, August, 1964, pp. 18-22

PURPOSE: To discuss the problem of defining and predicting the reliability of man in a man-machine system.

ABSTRACT: Many of the systems resulting from modern technology are extremely complex. When man is added to such a system, and the reliability of the combination is considered, a formidable problem is faced. To cope with it, a broad range of disciplines is required in the field which has been called biotechnology. The structure of biotechnology is indicated briefly. The role of the physician with a particular interest in environmental problems is described.

It is necessary to define man in his role as part of a system, and hence to devise ways of predicting his reliability. Man is capable of performing some tasks better than any existing machine; there are other tasks for which a machine is more effective. These are outlined. The specialized responses and reactions of man not found in the machine are discussed in terms of (1) biological environment, (2) chemical environment, and (3) sociological environment. Both man and machine respond to the physical environment. While at present the prediction of man's reliability is largely a matter of extrapolation based on informed guessing, there seems to be some potential for developing predictive processes in the future.

The reliability of the human element in the system may be enhanced through (1) selection of individuals fit for the job, (2) maintenance of fitness in those selected, and (3) training of various kinds. The factors affecting the reliability of the machine portion of the system are contrasted with those pertaining to man. Finally, the factors affecting the reliability of the man-machine system are considered.

REVIEW: This paper is an effective discussion of the broad aspects of the reliability of the man-machine system. The problem is of fundamental importance in the design of such man-machine systems as spacecraft. As the authors have pointed out, an interdisciplinary approach and cooperative effort involving many specialties will be required. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1591
Code 782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effect of temperature and vacuum on materials for use in the space environment

AUTHOR: D. Babusci, Bell Telephone Laboratories, Inc.

SOURCE: The Journal of Environmental Sciences, vol. 7, August, 1964, pp. 23-27

PURPOSE: To describe the results of a program of materials testing performed in a vacuum chamber to simulate certain space conditions.

ABSTRACT: During the construction of communication satellites the need arises to evaluate materials which can withstand the varying temperatures and vacua of the space environment over prolonged periods of time. Since little reliable data have been available in the literature on the effects of long exposures of pertinent materials to heat and vacuum, a vacuum chamber to simulate certain space conditions was built and the results of this materials testing program are described in this paper.

The vacuum station was designed essentially as a preliminary screening station for materials. As a result of the data obtained from this station, materials and components were selected for use in a satellite with the confidence that they would satisfy the structural and electrical requirements during the useful life of the satellite.

Environmental parameters of interest are described. It is indicated that measurement of weight losses was selected as the most efficient approach for the studies which were undertaken. For reasons of feasibility, economy, and time, nuclear radiation effects were not considered. The apparatus used is described. Detailed results are given on the testing of dielectric and insulating materials, structural materials, paints and finishes, and adhesives. (Author in part)

REVIEW: The author has succeeded in packing a lot of useful information into a relatively short paper. The results cited should be of interest and value to designers concerned with the selection of materials for use in the space environment.

Large-scale apparatus for the simulation of the heat and vacuum aspects of the space environment (by contrast with the small-scale equipment described in this paper) is the subject of the paper covered by Abstract and Review Serial Number 1587. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1592
Codes 815;816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability vs. reality

AUTHOR: Maj. Gen. Frank H. Britton, Deputy Commander, Second United States Army (formerly Director of Research and Development for the Army Materiel Command)

SOURCE: Environmental Quarterly, vol. 10, June, 1964, pp. 26-28 (extracted from Maj. Gen. Britton's keynote address to the 1964 meeting of the Institute of Environmental Sciences)

PURPOSE: To discuss the determination of realistic reliability requirements in the design and development of new systems.

ABSTRACT: The Army Materiel Command is committed to the concept of total reliability, which means the probability of a device functioning in the required manner for prescribed periods in delineated military environments. In order to determine and implement a reasonable reliability requirement for a new item or system, it is necessary to (a) define the project, (b) establish realistically the spectrum of environments, and (c) evolve a testing program to assess the ability of the equipment to perform the mission.

Project Definition, recently added to the Army's Research and Development cycle, is a formal three-phase process whereby preliminary engineering, contract and management planning are accomplished in an atmosphere that encourages thoroughness, realism and objectivity. Phase 1 asks for proposals from all interested and qualified contractors. Phase 2 is a funded effort, whereby one or more contractors are selected from Phase 1 participants to work closely with the government in establishing firm and realistic specifications, selection of the best technical approaches, establishment of the management plan, identification of the high risk areas, and development of good cost estimates. Phase 3 is a refinement phase during which the work in Phase 2 is evaluated, a contractor selected, and final specifications are written.

Other topics which are considered briefly include cost considerations, real vs. legal conditions, correlation of laboratory and field tests with actual operation environments, and the role of the environment. It is pointed out in conclusion that reliability is a function of environment, which must be evaluated realistically. The information must be communicated to the project engineer and designer in finite terms, in order to avoid repeating old mistakes and to put us on the road to reality. (Author in part)

REVIEW: This paper conveys a good message clearly and concisely. Its main theme, that of being completely realistic about all phases of the task from concept to field use, should be borne in mind by all concerned with reliability specifications for new systems. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Introduction (to Reliability Control in Aerospace Equipment Development)

AUTHOR: John de S. Coutinho, Grumman Aircraft Engineering Corporation and Polytechnic Institute of Brooklyn

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4 (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price:- $8.75), pp. 11-19

PURPOSE: To introduce a document prepared to assist engineers in performing their function of assuring that reliability is designed and built into their products.

ABSTRACT: This document is prepared for the benefit of individual SAE members and other engineers, to assist them in their daily work as designers on the drawing board, as project, test and specification engineers, and as first level supervisors associated with hardware development. It is aimed at the individuals who directly influence the reliability designed into the product. The limited discussions of reliability control techniques included in this book are intended to give engineers general background so that they can better understand all facets of the reliability problem and their relationships with development functions.

A review of the literature and manuals of many large companies reveals that there are divergent opinions as to the proper approach to reliability problems. Too often the remedies proposed involve three extreme approaches:

1. A pious appeal for the highest quality in design and manufacture, coupled with good technical judgment in design.
2. Extensive testing of a large population of items in order to establish failure rates with a high level of confidence.
3. Recommendations for elaborate mathematical exercises applied to failure data, amassed during extended use, of relatively common or standard parts and components which should have long since been redesigned.

Reliability control is needed for several reasons: projects are so large and complex that one person cannot be familiar with all the details; the time limits do not allow many traditional cut-and-try methods; reliability goals are more stringent. The reliability of a product is primarily determined in four basic areas of effort:

1. Design and development (including testing).
2. Manufacturing.
3. Logistics.
4. Human factors (including operator effectiveness).

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

A reliability control program must recognize the difficulties in making exact measurements of, or even exactly defining, the reliability of a complex system. In this event the design engineer must use much "engineering judgment." There must be a plan of action, many check lists, much follow-through--from design through field use.

The use of statistics and probability is difficult for many engineers since they were not specifically trained in them. However, it is important that the engineer understand these concepts well enough to use them intelligently. There is a need for better understanding between the engineer and the statistician.

Specialists in reliability can perform valuable services, both as advisers and in contributing to their portion of the design-production effort. (Author in part)

The document to which this paper is the introduction includes the following Parts:

Part I:	Inherent Reliability Design Practices
Part II:	Testing for Reliability
Part III:	Reliability Monitoring
Part IV:	Supplier Products Reliability Control
Part V:	Program Management
Part VI:	Contracting for Reliability
Part VII:	Mathematical Concepts

REVIEW: This is a good realistic introduction to reliability although the section on "The trouble with statistics" does not seem very clear. In general the tone is one of practical realism which says that the job cannot be done in the traditional ways and that the design and production of complex systems today requires people with skills in the field of reliability.

The book as a whole is very good and is highly recommended as an introductory guide for development engineers. (There are a few points which could have been improved; these are mentioned in the reviews of the separate Parts--see Abstracts and Reviews Serial Numbers 1594 through 1600). ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1594 -1
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Inherent reliability design practices

AUTHOR: Fred E. Marsh, Airplane Division, The Boeing Company

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4 (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price: $8.75), pp. 21-55

PURPOSE: To give an insight into the nature of reliability and how a designer incorporates it into his work.

ABSTRACT: The hazard rate of an equipment follows a time curve similar to that of human mortality. There is an infant period of high hazard; an intermediate period of low, relatively constant hazard; then a final wearout period of increasing hazard. The exponential distribution, which has a constant hazard rate, is useful for describing reliability during the intermediate period. The stress-strength concept of failure is introduced; i.e., failure occurs when some generalized stress exceeds some corresponding strength. Control of the stresses and strengths is important during the design and manufacturing phases. The reliability of a newly designed equipment tends to be low and then increases as more experience is gained with it. This is called reliability growth and tends to be most pronounced with radically-new, complex systems. The length of the mission is an important factor in reliability, as are the criteria for success and failure.

Attainment of reliability is accomplished through intensive planning followed by appropriate controls applied at every stage of design. During design, the goals for the system and the exact criteria for meeting them must be developed. In some cases, partial failures will not cause a system failure. Reliability studies are useful in comparing different designs, especially those with differing complexity. Other things being equal, complex systems are less reliable than simple ones, especially when severe environments are encountered. Design principles for reliability are the same as logical principles for all design. Some of the things a designer must consider are: the effects of environment, what safety factors or safety margins to use, approved parts and circuits, the proper materials to use, how to use the results of development tests, how the equipment will be maintained, the fact that known materials with few failure modes are usually better for reliability than relatively unknown ones, how quality of parts and materials will actually be checked, what manufacturing processes will actually be used, the human factors--especially those relating to the operator. Many check-lists for various phases are available to designers and should be used.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Once an equipment is conceived and a reliability goal is set, the performance and reliability goals for subsystems must be properly allocated. Some guiding principles and an example of reliability apportionment are given.

When a design is reasonably complete, the reliability should be calculated. For "ball-park" calculations, the assumption of constant hazard rate is usually made. When items are logically in series (when one fails, the system fails) the hazard rates add; when they are logically in parallel (when one works, the system works) the calculations are more complicated--some formulas are shown.

In order to be sure the design is optimum, the ways in which each part can fail and the effects of that kind of failure should be analyzed. Not only the effects on the equipment itself must be noted, but, for safety purposes, the effects on nearby people and equipment must be estimated.

The quantitative measures of maintainability and reliability are introduced. Many references are given throughout.

REVIEW: As a general introduction to the problems of designing for reliability, this is probably adequate, but not outstanding. The design review is not mentioned in this Part, but is well covered in other Parts. A large part of any discussion on designing for reliability can be summarized by the phrase "infinite attention to detail."

The concept of inherent reliability, while fairly widely used, tends to be poorly defined and inadequate. Every phase of the effort from concepts, through design, purchasing, manufacturing, usage, etc. is important and contributions to long or short life are made at each stage.

The concept of random failure during the intermediate period of life is inadequately handled. See Review Serial Number 1216 for a more complete discussion on this point.

The stress-strength model of failure is not yet completely general. It does have many applications, but other models tend to be more convenient in such areas as corrosion, fatigue, and wear.

There is an inconsistency in the definitions of maintainability--probably editorial in nature. That on page 33 is quite different from that on page 54 and the latter is more useful.

An unstated assumption in the reliability calculations of parallel networks is that the failure of one unit in no way affects the

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

failure rates of the remaining ones, although the assumption is explicitly made for series networks. If there are several possible environmental profiles, the classification of independence is more difficult to make. This is an important and severe restriction. The model of network failure in terms of part failure in this analysis is also limited. It assumes only one kind of part failure; in fact, many parts can exhibit more than one kind of failure (e.g. open and short) and a model based on this will give different answers from those in the text.

In any such discussion on reliability it must be emphasized that the results of a mathematical analysis apply only to the hypothetical system being analyzed. The results will fit a real system only to varying degrees and for varying purposes. A careful and informed comparison is necessary. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1595
Codes 770;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Testing for reliability

AUTHOR: John A. MacCarley, The Marquardt Corporation (now with Litton Systems, Inc., 5500 Canoga Avenue, Woodland Hills, California)

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4 (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price: $8.75), pp. 57-78

PURPOSE: To give a summary of reliability testing activities.

ABSTRACT: Tests are expensive and thus must be traded off against benefits of the tests. When high reliability or low hazard rate (assumed constant) are desired, and the scatter in the data is large, the requirements of reasonable costs and accurate estimates are virtually contradictory. There will usually exist some reasonable compromise for minimum overall program costs. There are tests for different purposes and the names for them can appear to present a wide divergence of objectives. However, reliability tests can be categorized as development, qualification, reliability demonstration, or acceptance; these are discussed. In running the tests, failed items may be not-replaced, repaired-and-replaced, or replaced with new items. It is easy to estimate the number of items to place on test initially for minimum test cost under any of the three options if the various sub-costs of testing are known.
Three ways of demonstrating reliability in common use today are:

1. Successes/Trials Procedure: Tests are run for the mission time and the ratio of successes to trials is calculated. The F distribution is used to determine confidence limits. This is a non-parametric method which requires no assumption about the probability density function of the lifetimes.

2. Parameter Estimation Procedure: This is usually but not always based on the exponential distribution of lifetimes. The chi-square distribution is used to calculate confidence limits.

3. Truncated Sequential Test Procedure: After each failure, one of three decisions is made: continue testing, stop and accept the lot, or stop and reject the lot. The formulas for consumer's and producer's risks are given.

Examples, tables and graphs are included.

REVIEW: This is a quite adequate introduction to reliability testing, test planning, and associated computational methods. However, the stress-strength model of failure is not as general as is implied in the text. In the example on parameter estimation by single sampling it is explained that the test can be terminated "ahead of time" by checking the time after each failure. If this is done, the probability levels are no longer correct, as the test has then become partially sequential. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1596
Codes 815;841;845;
864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability monitoring

AUTHORS: Charles H. Koehler, Jr., Lockheed Georgia Company and Donald F. Smith, Stratos Division, Fairchild Stratos Corporation

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4 (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price: $8.75), pp. 79-93

PURPOSE: To summarize reliability monitoring and data collection activities.

ABSTRACT: Certain techniques and practices are commonly used in monitoring a product reliability control program. The primary reference document is USAF Specification Bulletin No. 506. The techniques and practices described are applicable from time of bid proposal preparation until the product has been phased out of use by the customer. Only through systematic monitoring of significant milestones during its life span can a product reliability control program be made effective. The tasks that a contractor should perform in order to conduct a fully integrated reliability control program are presented in reasonable chronological order. They include control of procurement requirements, control of "non-standard" functional items, failure trends investigation, corrective action and evaluation, etc.

In order to do an effective job, the designer must have access to parts reliability data in a convenient, comprehensive and easy-to-use form. The properties of such systems for collecting, organizing, and supplying information are summarized. Details of many specific systems are readily available in the literature.

REVIEW: This is a very good summary of the topics mentioned. It will require much study because the subject matter is so condensed. Whole papers have been written on many of the sub-topics. Nevertheless the chapters will be very valuable to designers who are really interested in high reliability.

(One minor comment concerns the statement "... Reliability degradation begins at the time a design leaves the designer's hands...." There are some unfortunate implications here; the designer is neither that good, nor the rest of the production complex necessarily that bad.)

Papers on other agencies or groups concerned with the collection and exchange of data have been covered by Abstracts and Reviews Serial Numbers 27, 54, 56, 169, 406, 877, 901, 905, 926, and 934.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1597
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Supplier products reliability control

AUTHOR: W. L. Johnston, General Dynamics/Convair

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4 (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price: $8.75), pp. 95-102

PURPOSE: To discuss the controls on items affecting reliability which it is necessary to have with a supplier.

ABSTRACT: Many parts or subassemblies are purchased rather than made in-house. It is necessary to have accurate, comprehensive communication with each supplier. These points are discussed under the subjects: reliability requirements of a specification; procurement specifications: performance and testing; supplier selection; evaluation of bid proposals; coordination of design with supplier; first-article conformity; qualification testing; control of production changes; quality control activities; reliability data interchange with supplier.

REVIEW: This is a good summary in which each subject is discussed realistically (although, necessarily, briefly). The advantages, problems, etc. of each phase are clearly brought out and put in perspective. As with other parts of this book, study, rather than casual reading, will be necessary because the material is so comprehensive and important. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1598 -1
Code 810

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Program management

AUTHOR: John de S. Coutinho, Grumman Aircraft Engineering Corporation and Polytechnic Institute of Brooklyn

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4 (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price: $8.75), pp. 103-129

PURPOSE: To show what an engineer should know about reliability as it relates to program management.

ABSTRACT: The general principles of managing a reliability program are not well defined. However, a number of technical reliability control principles have been developed and some engineers are skilled in their application. Yet it is difficult to find many effective programs. This leads to the conclusion that it is not easy to organize and implement an effective reliability control program.

Controls during the design phase are the keystone of a reliability control system. Reliability must be inherent in the basic design. If the system or hardware design is deficient at the start, no amount of reliability control in any other area can ever correct or make up for the design defects. Nevertheless, reliability control during the design phase is usually the weakest point in any reliability control program. Reliability control activities take place on two levels. One level is associated with the program management, the other with the design, material procurement, manufacturing, and logistics. An optimum reliability program is tailored to the problems associated with a specific type of product as well as with the characteristics of the organization, its personnel, facilities, and the operating philosophy of the management. It gives proper weight to the problems of design and development, production, maintenance, and supply. Various aspects of the problem of determining reliability goals are discussed.

The formal design review meeting is one of the standard methods for assuring that all significant factors have been considered in the design approach. The requirements of a good design review are cited. The provisions for review and approval of a supplier's failure rates and estimating procedures are important in all cases where stringent reliability requirements exist. Problems in this connection are indicated. The reliability control program should assure that even the first prototype will be as free as possible of troubles and breakdowns. The design should be debugged as much as possible on paper before it is built and tested. The reliability control engineer can provide an outside unbiased (or differently biased) view which can often detect faults not

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

apparent to those so closely involved.

Testing may be classified as development, qualification, acceptance, reliability, and flight tests. The characteristics of each of these types are described. The steps to be taken to ascertain that the fabrication facilities and processes are suitable for the production of a product that will satisfy the reliability requirements are outlined.

Given the life of the equipment and the lives of all its components, it is possible to lay out a scheduled maintenance program so that every item will be replaced before it wears out. Although a designer may not know the exact scheduled replacement rate of the various components in his equipment, he can estimate the relative longevity of these items and provide for accessibility and ease of removal in accordance with this estimate. Components with the shortest estimated lives should be the most accessible and the easiest to remove. Such items should normally be interchangeable with one another. Unscheduled maintenance activities involve trouble or fault detection, location and isolation of the failure, and repair or adjustment. When automatic check-out equipment is used, the system must be designed so that the operation of every significant function can be checked out, individually and in all critical combinations, by check-out equipment that is external to the system, and when the system is in its operational configuration or as close to it as possible. Thus the check-out operation must be considered throughout the system design and the check-out equipment must be developed concurrently with the system. The role of the reliability program in providing adequate check-out equipment and ensuring ease of maintenance is indicated.

Other topics considered include effective reliability control over supplier products, utilization of service experience in the reliability control program, and the control and analysis of data. Related managerial considerations which are discussed include the selection and training of reliability control engineers, the contractual significance of reliability requirements, incentives for reliability, and the need for top management support.

REVIEW: This is a jam-packed Part and is more informative for engineers than the title would suggest. It accomplishes its stated purpose quite well and is worthy of the thoughtful attention of those concerned with reliability control in design and production. Most of the points are good; many are excellent. (One or two points, all incidental to the main theme, are made not too well and have been covered in reviews of earlier parts.) The author has been quite realistic in saying how things really do get done in the real world, but equally realistic in his demands on how the situation can be improved. ##

Serial Number 1599
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Contracting for reliability

AUTHOR: R. H. Johnson, Space Systems Division, Martin-Marietta Corporation

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4, (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price: $8.75), pp. 131-143

PURPOSE: To discuss the best means of specifying reliability in contracts.

ABSTRACT: In addition to the first five sections of the paper covered by Abstract and Review Serial Number 539, this paper contains abstracts of the following Government reliability specifications:

MIL-R-27542 (1) (USAF), 28 June 1961: Reliability Program Requirement for Aerospace Systems, Subsystems, and Equipment

MIL-STD-441, 20 June 1958: Reliability of Military Electronic Equipment

MIL-R-26474, (USAF), 10 June 1959: Reliability Requirements for Production of Ground Electronic Equipment

MIL-R-27070 (USAF), 25 March 1960: Reliability Requirements for Development of Ground Electronic Equipment

MIL-R-27173 (USAF), 6 July 1959: Reliability Requirements for Electronic Ground Checkout Equipment

MIL-R-26484 A (USAF), 18 April 1960: Reliability Requirements for Development of Electronic Subsystems or Equipment

MIL-R-22256 (AER), 20 November 1959: Reliability Requirements for Design of Electronic Equipment or Systems

MIL-R-22732 (1) (SHIPS), 31 July 1961: Reliability Requirements for Shipboard and Ground Electronic Equipment

USAF SPEC. BUL. 506, 11 May 1959: Reliability Monitoring Program for Use in the Design, Development, and Production of Air Weapons Systems and Support Systems

MIL-R-26667A (USAF), 2 June 1959: Reliability and Longevity Requirements, Electronic Equipment, General Specification For

MIL-R-22973 (WEP), 16 October 1961: Reliability Index Determination for Avionic Equipment Models, General Specification For

MIL-STD-756 (WEP), 3 October 1961: Reliability of Weapons Systems, Procedure for Prediction, and Reporting Prediction of

Topics covered, in general, are: Applicability, Scope, General Requirements, Test Requirements and Timing, Documentation Requirements and Timing, Requirements to be Negotiated and Timing, Samples Required, Special Facilities and Equipment Requirements, Applicability to New Design, and Conflict with other Specifications.

REVIEW: The first part of this paper was covered by Abstract and Review Serial Number 539. The abstracts of the specifications should help those who wish to get the cited information quickly. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1600
Code 820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Mathematical concepts

AUTHORS: Lionel Levy, Republic Aviation Corporation and Fred E. Marsh, Aero-Space Division, The Boeing Company

SOURCE: Reliability Control in Aerospace Equipment Development, Society of Automotive Engineers Technical Progress Series, vol. 4 (published by Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York 17, New York; price: $8.75), pp. 145-185

PURPOSE: To present a guide to mathematical concepts applicable to reliability.

ABSTRACT: After a brief introduction to the rules of probability manipulation, terms such as failure rate, hazard rate, and MTBF are defined and explained. The exponential distribution (constant hazard rate) is introduced and used. Series/parallel arrangements of items are analyzed and redundancy is explained. The terms series and parallel apply to the logic diagram, not to the physical situation. A procedure using Bayes' theorem is explained for evaluating more complicated diagrams.

The various statistical distributions which are useful in reliability analysis are listed, together with a discussion of their probability density functions. There is a brief introduction to statistical inference, including parameter estimation and hypothesis testing. A final chapter gives a number of tables and graphs which are useful in making reliability calculations.

REVIEW: This Part generally maintains the high standards set by most of the earlier Parts. Again, the compactness of the material means that the beginner must study it if he is to benefit from it.

(There are a few minor distractions:

1. The concept of random failure is not handled too well, as all failures which are discussed are random, even in wearout and infant mortality. The term "intermediate region" is better.
2. There is a misprint in Eq. 18.11: k/n should be k/h.
3. The "exponential" assumption may not always be on the conservative side.
4. In a few places it is not quite clear that the result applies only to the "exponential" case.
5. There is not controversy about Bayes' Theorem itself. Its application to some practical problems, however, must be approached with extreme caution. In this connection it is wise to point out that the use of conditional probabilities can be very tricky indeed, even for non-beginners.

But these distractions are not serious and do not detract from the overall good quality of the presentation.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1601
Codes 760;813

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Auto diode Q&R program--military reliability plus

AUTHOR: W. P. Kauffman, Q&R Dept., Westinghouse Semiconductor Division

SOURCE: Evaluation Engineering, vol. 2, September/October, 1963, pp. 6-7, 9-11

PURPOSE: To describe the Reliability Certification Program for silicon diodes used in automotive alternators.

ABSTRACT: Each alternator on a car uses six silicon diodes to produce the required dc. The reliability and quality requirements on these diodes are very high, although they do vary between companies.

In the program described, the Q&R department manager reports directly to the plant manager. Incoming inspection complies with military requirements. Inprocess inspection uses both continuous and independent monitoring of the processes. Defective material is kept track of until disposition is complete. The Q&R patrol inspectors check parameters of the processes in order to detect any important deviations.

The engineering drawings and specification controls are similar to those required by the military--very stringent. Lot control and identification is more complete than required by the military since it enables absolute lot identification even before bonding the stock.

Acceptance tests for production lots are similar to the military. Some of the tests are more accelerated and specific since there is only a single application for the product. Sample sizes are fixed to preserve the consumer's risk rather than as in MIL-STD-105. Some examples of the tests are given. After environmental and life tests of the samples, the electrical parameters are compared with the initial ones.

This program has helped bring military reliability standards into commercial practice and has enhanced reliability engineering.

REVIEW: This paper gives a feeling for some of the problems involved in supplying high-reliability parts on a commercial basis. It is not intended to go into all phases very deeply. The reader may wonder if the diode manufacturer assumes any responsibility for the two-year automotive guarantee. The author, in a private communication, has answered this question as follows: "We do not assume any part of the two-year automotive guarantee to the customer; however, we do have extremely rigid test requirements from our customers which force us to accept our liability before the ultimate customer actually purchases his automobile." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1602
Codes 720;764

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Probability of escape..a case study

AUTHOR: Lucille R. Diamond, Product Assurance Department, Sylvania Electronic Systems

SOURCE: Evaluation Engineering, vol. 2, September/October, 1963, pp. 16, 18

PURPOSE: To present a case study of improving the AOQL of complex equipment.

ABSTRACT: The total manufacturing plan for a complex communications system was analyzed in terms of incoming inspection, fabrication and final inspection and test. The AOQL calculated after inspection was integrated into the particular fabrication operation utilizing the parts values resulting in the AOQL's as shown.

Operation	AOQL%
Mechanical Hardware Fabrication	0.5%
Module Assembly, Inspection and Test	3.6%
Cable Fabrication	1.0%

The sum of the AOQL's is 5.1%. Assume that each of two inspections will catch only 80% of the defects that were introduced since the previous inspection; then the outgoing AOQL is 5.1%/(80% x 80%) = 8' This was much too high and the processes were examined in detail for possibilities of improvement. The fabrication of printed circuit boards and their assembly with components was automated and the AOQL was significantly improved. There were also several poorly designed processes, lack of tight controls, and latent part failures which did not show up in incoming inspection. There were significant differences between test operators. After revising the manufacturing process, retraining test operators, etc., the AOQL was reduced from 8% to 3.8%. A change in requirements was then negotiated with the customer.

REVIEW: This is a brief qualitative description of quality improvement by analyzing the manufacturing and testing operations and making appropriate changes. The use of the term "reliability" in this paper is not too clear. For example, the relationship AOQL + R_1 = 1 is used, in which R_1 denotes the reliability allocated to the manufacturing process. If reliability is used in the sense of probability of successful mission completion (given that the item worked at the beginning), then the terms R_1, R_D (reliability allocated to design), and R_U (use reliability) are not at all clear; nor is the equation $R_0 = R_1 \times R_D \times R_U$, where R_0 denotes operational reliability, very meaningful. The phrase "...which were still in the infant mortality region of the exponential distribution." is confused at best. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1603 -1
Code 815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: What the Air Force expects in reliability programs from its contractors--MIL-R-27542 and ? Parts I and II

AUTHOR: Major James R. Barton, Chief, Engineering Requirements Division, Technical Requirements and Standards Office, United States Air Force

SOURCE: Evaluation Engineering, vol. 2, September/October, 1963, pp. 22-23 and November/December, 1963, pp. 9-11

PURPOSE: To discuss recent updating of the USAF policy document and specification(s) on the reliability and maintainability of systems, subsystems, and equipments.

ABSTRACT: The Air Force recognizes the importance of reliability and maintainability as major design parameters, comparable in impact with performance. Requirements and procedures have been established to govern the actions of the procuring activities to assure acquisition of reliable and maintainable equipment at minimum cost. Headquarters, USAF published AFR 80-5, Reliability Program for Systems, Subsystems, and Equipments, on June 4, 1962 (superseding AFR 375-5), which establishes Air Force policy and requirement for an aggressive and comprehensive reliability program. It is clearly enunciated that each program for which a contract is written shall include realistic quantitative reliability requirements, a stated minimum acceptable confidence level, and a stress level for the environmental condition of demonstration. To emphasize the extent to which the program is to be enforced, policy states that if contract reliability requirements, including contractor's effort, are not met, monetary penalties or other actions will be considered. The implementing vehicle of this policy is MIL-R-27542 (USAF), Reliability Program Requirements for Aerospace Systems, Subsystems, and Equipment, which will eventually be a consolidation of all reliability specifications. Implementation of this reliability policy and specification by the various USAF Systems Divisions is discussed. Major tasks of an over-all program are presented and discussed. These include: (1) design reviews, (2) mathematical models, (3) statistical engineering, (4) failure reporting and correction, (5) monitoring points, (6) supplier management, (7) human engineering, (8) after-manufacture handling effects, (9) handbook controls, (10) test and demonstration, (11) weak links chart, (12) training program, and (13) reports.

REVIEW: Experience and growth are reflected in the cited documents which are improvements over their predecessors. Perhaps the greatest current need is for increased meaningful implementation.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

It is still not unusual for proposal requests and the subsequent program plans to have reliability quantitative-requirement and program tasks stated in confusing terms, or not stated at all. This results in programs which are either a low-cost, lip-service approach (often for competitive reasons) or a high-cost type of program which makes no effective contribution. Some reasons preventing widespread effective implementations of the cited USAF policy and specification are [1]:

1. Lack of valid data on the true costs of unreliable systems.
2. Lack of understanding by high-level management, and contract control groups.
3. Confusion relative to reliability, quality, and associated functions.
4. Frequent conduct by industry of costly, unproductive reliability programs.
5. Lack of coordination between government project and reliability groups.
6. Lack of properly stated quantitative reliability requirements in requests for bids.

Thus the efforts described in this paper appear most appropriate. The discussion of USAF (and other governmental agency) policies and specifications by appropriate officials is desirable and of extreme interest to industry. It is to be hoped that subsequent improvements will continue, and, in particular, that evidence will be presented substantiating policy fulfillment, i.e. acquisition of reliable and maintainable equipment at minimum cost for each program.

For additional remarks on this specification, see Abstracts and Reviews Serial Numbers 1202 and 1404.

REFERENCE: [1] E. F. Dertinger, "Funding Reliability Programs," Proceedings Eleventh Annual Western Region Conference sponsored by the Portland, Oregon Section of the American Society for Quality Control, April, 1964, pp. 315-335 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1604
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: An ex-designer tells how to maximize reliability by minimizing overdesign

AUTHOR: Jacob M. Shapiro, Epsco, Inc., Cambridge, Massachusetts

SOURCE: Evaluation Engineering, vol. 2, September/October, 1963, pp. 24, 26

PURPOSE: To show that proper allocation of performance goals can reduce overdesign and associated problems.

ABSTRACT: Engineers tend to introduce excessive safety margins in assigning performance goals to subsystems. If these goals were properly derived from system specifications and if a thorough tolerance (on performance) analysis were made, many subsystems could be simpler and more reliable. Designers seem to forget that complexity tends to breed unreliability. The reliability engineer can help assure good design by assisting the designer in making these calculations and then revising them as the design progresses. Standard and preferred circuits can be a big help in this regard, since their properties are well known.

REVIEW: The author's essential points--careful and exact consideration of design goals for subsystems--are good. Engineers may tend to overdesign; but in other places they certainly tend to underdesign and use too small safety margins. The author's suggestions are good and probably can be fitted into the program--although not always in the person of the reliability engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1605
Code 555

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Plain talk on reliability nomographs, Parts I and II (reliability mathematics corner)

AUTHORS: A. A. Rothstein, S. Loew, E. Kay and V. Liuzzi, Reliability Department, Avco Corporation, Research and Advanced Development Division

SOURCE: Evaluation Engineering, July/August, 1963, p. 27 (Part I), September/October, 1963, pp. 28, 29 (Part II)

PURPOSE: To introduce sampling concepts and give a nomograph for solving the equations for the binomial situation.

ABSTRACT: In the binomial situation (events are classified as success or failure), one can make a point estimate of average fraction of successes by taking the ratio of successes to trials. Especially with small samples, the estimate may not be accurate. If an interval rather than a single value is given, the interval may or may not contain the true average. Confidence is the fraction of times that the interval does contain the true value. The treatment here gives a "one-sided" interval, viz. the true value is asserted to be above the calculated one. The nomograph for these calculations is given.

REVIEW: In general this article is satisfactory. Even though material is presented in a simple way, the presentation should not be incorrect. The point estimate given is a very common one, but it is not the only possible one and is "best" only with regard to certain criteria (in this case the criteria it satisfies are also quite common). When the random variable can take only discrete values (is not continuous) as in this case, the confidence statements are more accurately expressed as bounds, e.g., the confidence is <u>at least</u> 75% that the true value is greater than 0.867. It is helpful in checking (for possible errors of authors, editors, or printers) if the equation which the nomograph purports to solve is stated. In a private communication the author has indicated that the nomograph was derived from tabulated values of a computer run using equation 21.11.5 in A. Hald, "Statistical Theory with Engineering Applications" 5th Printing, November 1962, p. 698, i.e.,

$$\underline{\theta} = x_o/[x_o + (n - x_o + 1)v^2_{P_2}]$$

for $f_1 = 2(n - x_o + 1)$ and $f_2 = 2x_o$. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1606
Codes 775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to evaluate diodes for contamination

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, November/December, 1963, pp. 6, 21

PURPOSE: To list some of the ways of inspecting (glass) diodes.

ABSTRACT: The publicity on diode contamination in the Ranger VI program will cause evaluation engineers to take a closer look at their diodes. Optical microscopy and X-rays are the two main ways of nondestructively examining the diodes. Proper equipment properly used is, of course, essential. Some examples of poor diodes are shown.

REVIEW: This is a short interesting summary of the subject. Other papers which treat it in more detail have been covered by Abstracts and Reviews Serial Numbers 1462 and 1514. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1607
Codes 844 ; 864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Weapon system MTBF problems and solutions

AUTHOR: E. W. Kimball, Reliability Group Engineer, Martin Company

SOURCE: Evaluation Engineering, vol. 2, November/December, 1963, pp.12, 13, 15

PURPOSE: To present the best possible numerical reliability practices.

ABSTRACT: In the past, failure reports have been written by field service and logistics personnel. Because data gathering is not their primary job, run time information is often omitted. Field service personnel are usually too busy maintaining equipment and insuring the smooth flow of spare components to worry about obtaining accurate data. Run time meters can provide this information quite easily if they are incorporated in the equipment. Otherwise, it has been found highly beneficial to assign a reliability representative to field locations. His specific job is securing complete run time information and other data required by reliability. He maintains log books and can also determine if failures are caused by operator error, or are secondary in nature. These malfunctions will then be left out of the MTBF calculations in order that reliability is not unfairly biased. (Author in part)

REVIEW: The stated purpose of the article appears to be misleading, although the paper is interesting and informative in its own right. The problem of accuracy of field data has been treated rather extensively in the literature; papers in this topic area which have been covered by RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS are found under the Code 864. The proposals presented in this article are not necessarily optimum in all cases. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1608
Codes 423;824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of time-independent devices (reliability mathematics corner)

AUTHOR: Thomas A. Simonds, Electro-Mechanical Research, Inc.

SOURCE: Evaluation Engineering, vol. 2, November/December, 1963, pp. 18-19

PURPOSE: To show how to calculate confidence limits on reliability for the case in which the mission is classified only as success or failure (binomial case).

ABSTRACT: In some cases, of which a squib igniter is typical, interest centers on success or failure, and no time element is involved. This is the binomial case and reliability, the probability of success, is estimated as the ratio of the number of successes to the number of trials. The author places confidence limits on this estimate by the use of a χ^2 statistic. A numerical example and three illustrative figures are given.

REVIEW: The problem treated in this paper is merely that of placing a confidence interval on the parameter of the binomial distribution. Charts for this purpose are available in most textbooks on statistical methods. The author's approach, using the χ^2 statistic, is actually an approximate method, although he does not indicate this. Furthermore it seems somewhat awkward in view of the charts and tables available for this purpose. A nomograph for determining one-sided intervals in the binomial situation was presented in the paper covered by Abstract and Review Serial Number 1605. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1609
Code 873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluate connections with a maintainability figure of merit

AUTHOR: John E. Rutledge, Jr., Project Engineer, Radio Corporation of America, Missile and Surface Radar Division

SOURCE: Evaluation Engineering, vol. 2, November/December, 1963, pp. 20-21

PURPOSE: To propose a method of measuring one aspect of equipment design.

ABSTRACT: The term maintainability percentage is introduced with respect to connections. It is split into three parts as follows: time (50% maximum), talent (25% maximum) and tools (25% maximum). The following table is used to evaluate the maintainability percentage for a connection (100% is best):

Time	%	+ Talent	%	+ Tools	%
Effectively None	50	Unskilled	25	None	25
Short	25	Semi-skilled	15	Common	15
Long	10	Skilled	5	Special	5

(Percent based on engineering experience and judgement.)

For example, a plug-in component rates 100%; a solder terminal component rates 30%. The average component rating in a system can easily be calculated. The maintainability figure of merit can be plotted against reliability.

REVIEW: The use of the term maintainability in the context of this paper is unfortunate since many are trying to standardize its meaning as something quite different from that used here. The figure of merit (average "maintainability") may well be a useful number for evaluating different configurations.

It is hard to see any tradeoffs on the reliability vs. figure of merit graph since they increase together monotonically. The author's alternate method is, of course, exactly the same as the original except that the numbers are all ten times as large. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The doghouse where reliability barks loud and clear

AUTHOR: A. C. Gorski, Senior Reliability Engineer, Autonetics

SOURCE: Evaluation Engineering, vol. 2, November/December, 1963, pp. 24-25, and letter to the editor, Evaluation Engineering, vol. 3, January/February, 1964, pp. 6, 36

PURPOSE: To philosophize candidly on what's right and wrong with reliability.

ABSTRACT: At the 1962 NEC Reliability Conference opinions were expressed, many of which allegedly represented management views on reliability. The author replies to the following two claims: (a) that production techniques and statistics will never build hardware, hence mathematics in reliability should be treated as a hobby, and (b) that the reliability function is a "window dressing effort", hence talented people are not present there. The essentials of the reply are (a) for best results the reliability group should combine engineers and mathematicians in a working team, and (b) managers should provide a climate in which enthusiasm and creativity can grow, in order to attract competent talent. The author concludes that reliability is a tool needed to verify field performance. Management must recognize its validity and know how to apply it.

In a letter to the editor (see SOURCE) the author to whom claim (a), above, was attributed replies that "straw issues" have been set up by quoting out of context. He goes on to "set the matter straight".

REVIEW: Taken together, this brief paper and the letter commenting on it are interesting to read and have some thought-provoking aspects. The author may have been setting up "straw issues" in the opinions of some, but he does make some worthwhile points. The letter in reply constitutes a reasonable rebuttal and makes some good points also. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1611
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: How to evaluate resistor design tolerances

AUTHOR: C. J. Stauss, Resistor Product Engineer, Corning Electronic Components

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 14-16, 43

PURPOSE: To show the advantages of using tighter-tolerance resistors.

ABSTRACT: Resistors have greater variation in resistance during their life than the purchase tolerance; however, it tends to be less than the sum of the absolute values of all the allowable variations. Since the variations due to each cause are independent, the variance of the sum is the sum of the variances. In an example, the expected tolerance is reduced from 11.5% to 6%. In practice, the mean of the distribution and the standard deviation can be calculated before and after aging. Several examples show the improvements to be gained by using tight-tolerance (at end-of-life) resistors. Some of the circuit improvements are greater fan-out, lower cost, higher reliability, lower power dissipation--although not all are obtainable at the same time.

REVIEW: This paper follows the general line of others published by employees of Corning (see, for example, Abstract and Review Serial Number 1504). Outside of some looseness in the treatment of statistical theory the paper is adequate (the examples were not checked in detail). Many of the comments in Review Serial Number 1504 apply also to this paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1612
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A new look at standards engineering

AUTHOR: N. M. Zizzi, Supervisor, Component Selection and Specifications Group, Engineering Standards Department, Chrysler Missile Division

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 18,20

PURPOSE: To show how standards engineering is related to reliability, value engineering, and maintainability.

ABSTRACT: A standards engineer by the very nature of his job provides a service function that has a direct impact on reliability, value engineering and maintainability. He not only maintains and encourages the use of approved standards; he also creates, develops, evaluates, selects, provides, documents, retrieves, collects and assembles engineering data for use in the design, development, production and maintenance of a product. Therefore, supporting these disciplines for the most part would be an extension of services he is already providing. He is well qualified and has the tools to support these groups because he has long recognized and understood their importance.

A chart is included to show the relationship of standards engineers' services to reliability, value engineering, and maintainability. (Author in part)

REVIEW: Good total engineering requires efforts in many areas. The requirements and limitations of the job at hand determine the relative emphasis on each field or effort. Standards are quite important and men specially trained to deal with them are helpful in any engineering endeavor. This article makes explicit the nature of this assistance. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1613
Code 810

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: SCORE: An effective reliability aid

AUTHOR: W. E. Garner, Jr., Manager, Components Engineering, Air Arm Division, Westinghouse Defense Center

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 22, 24-26

PURPOSE: To describe part of the overall reliability effort of the Air Arm Division of Westinghouse.

ABSTRACT: The Sub-Committee on Reliability (SCORE), with an active middle-management team in the mainstream of actions and decisions on each project, is proving to be an effective means of translating notions into motions in a large multi-product systems organization. The constant SCORE review of problems has produced an effective reduction in factory and field failures. (Author)

REVIEW: A panel on the higher-management level for establishing policy and coordinating departmental procedures, operating with subsidiary project teams, appears to have been found effective by this organization in achieving its reliability goals. This approach serves to establish effective communication among all pertinent departmental functions with higher management looking on, and to bring reliability problems into open visibility where they cannot be conveniently forgotten.

The article would be of interest to reliability management personnel in industry. Pertinency of this approach in another organization is, of course, dependent on how the organization establishes and achieves reliability and other goals. As reliability is just one of several goals of systems-producing organizations (other goals, for example, being performance, maintainability, schedules, and profits), other organizations may find it adequate to establish and achieve the reliability goal by whatever basic means they use in achieving the other goals. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1614
Code 836

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design review at General Dynamics

AUTHOR: J. E. Eichberger, Supervisor of Design Assurance, General Dynamics/Electronics

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 27, 28, 30

PURPOSE: To explain the design review policy and techniques at General Dynamics/Electronics

ABSTRACT: An organized design review program tailored to a specific product schedule is an effective planning tool, an evaluation technique, and an innovation medium. In bringing together a group of specialists who submit a new design to a knowledgeable scrutiny at predetermined critical phasing points, design review contributes significantly to the development of a mature, quality product which is developed within the budget and delivered on schedule. In this article, the design review policy and techniques which have been applied at General Dynamics/Electronics are reviewed, with emphasis on those areas of effort considered critical to program success.

In general, design review requires a number of review meetings scheduled to coincide with key program events. Each review phase may consist of many meetings, depending on the complexity and magnitude of the program. The following reviews are typical of those scheduled on programs at General Dynamics/Electronics:

1. Conception Design Review
2. Preliminary Design Review
3. Preproduction Design Review
4. Production Release Review

The purpose of the review is to identify and bring out into the open questionable topics, not necessarily to correct them. Competent project people have generally been assigned to take care of the design and manufacture of the item in question; therefore, attempts to redesign during a review meeting are discouraged.

The cost effectiveness has been estimated at more than three dollars saved per dollar spent on design review. (Author in part)

REVIEW: Design reviews are essential to the development of reliable products. This article appears to be a good summary of a good program.

It should also be realized that other operations in the product cycle, such as manufacturing, can also benefit from a similar formal review. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1615
Codes 552; 837; 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability safety margin chart (reliability mathematics corner)

AUTHOR: Austin J. Bonis, Reliability Research and Education Director, A. C. Spark Plug, The Electronics Division of General Motors

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 34-35

PURPOSE: To present a graph for calculating demonstration requirements for true MTBF (based on the exponential distribution).

ABSTRACT: If the behavior of a system is "exponential" and it is required that the reliability be demonstrated by a test, then the graph can be used to calculate the properties of the test. In general the true MTBF of the system must be appreciably higher than the specified MTBF if there is to be a small chance of wrongly rejecting the system on the basis of the test. The graph and examples of its use are given.

REVIEW: The graph and instructions for its use appear to be correct (they have been spot-checked). It is helpful in cases like this if the equation which the graph solves is given; it aids the readers and helps to protect against errors introduced in the publishing process. An appendix explaining the theory would be valuable, but its omission for reasons of brevity is understandable. The chart should be of value to those who have to make repetitive calculations of this sort.

An important assumption in this kind of test is that there is complete ignorance about the true MTBF before the test begins--all that is known is the information from the test. This is usually not an accurate description of the situation since the manufacturer does have some idea beforehand of what the MTBF is likely to be. This point is discussed more fully in Review Serial Number 1035. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1616
Code 773

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: 11 key questions on test equipment--and their answers

AUTHOR: (Editorial Matter based on an interview with Gordon L. Ness, Fairchild Semiconductor (Instrumentation))

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 38-39

PURPOSE: To point out important considerations for test equipment in high-reliability applications.

ABSTRACT: In taking test data for high-reliability evaluations it is important that meaningful tests be properly carried out and that all conditions be quite repeatable. If the equipment has modular design, the obsolescence problem is alleviated and repairs are easier. Test equipment should have 95% availability; if it is "solid state" it can easily be guaranteed for one year. The real cost of equipment is the actual cost per test. Speed, ease of operation, low skill level required of operators, automatic print-out, etc. will influence this cost. Correlation of test data with those of various component manufacturers must also be considered.

REVIEW: This is a short qualitative article in question/answer form. It will be of main interest to those new to the field. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improved design review check list

AUTHOR: Richard E. Shafer, Polaris Systems Support, Lockheed Missiles and Space Company

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 40-41

PURPOSE: To describe an improved design review check list.

ABSTRACT: The author has devised a check list design review method based on the Navy Electronics Laboratory booklet "Suggestions for Designers of Electronic Equipment." Requests for copies should be directed to the Commanding Officer and Director (Code 3060 G), U. S. Navy Electronics Laboratory, San Diego 52, California.

This check list effectively presents far more comprehensive information than would fit into reasonably sized conventional check lists along with simple forms which are easily used and filed. It consists of columns of figures corresponding to page and topic numbers appearing in the booklet referred to above. Three of the several methods available for use of the information are illustrated.

REVIEW: This is little more than an announcement of the availability of the check list. From the information given, it would seem to be a concise and reasonable method of record-keeping for the use of designers, engineers, and supervisors carrying out design reviews. The ten-point scale to indicate degree of compliance (Method II mentioned in the paper) should be useful if proper scale values can be realistically assigned at the various check points. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1618
Code 775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: 13 key questions on semiconductor X-ray evaluation

AUTHOR: (Editorial Matter based on an interview with Richard K. Dahlem, Semiconductor Specialists, Inc.)

SOURCE: Evaluation Engineering, vol. 3, March/April, 1964, pp. 14-16

PURPOSE: To discuss the X-ray evaluation of semiconductors.

ABSTRACT: At least 15 companies now have specifications for X-raying diodes, although there is little standardization. The X-ray dose so incurred does not damage the device. The X-ray picture does show many mechanical defects which are not otherwise detectable. X-ray examination is also expected to be helpful on integrated circuits. Important factors in X-ray specifications and suggested criteria for rejection are summarized.

REVIEW: This is a qualitative summary of the subject in question/answer form. The information supplements that in an earlier article in the same magazine (see Abstract and Review Serial Number 1606). The information will be most helpful to those who are new to the field. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1619
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability document control

AUTHOR: E. L. Eagle, Reliability Department, Lockheed-California Company

SOURCE: Evaluation Engineering, vol. 3, March/April, 1964, pp. 22-24, 26 and May/June, 1964, pp. 34, 36-40, 42-45

PURPOSE: To provide a reliability classification system and a set of reliability subject headings for organizing an effective filing system for reliability literature.

ABSTRACT: The filing of a document in such a way as to enable its retrieval when required is vital to the efficient use of literature. This is particularly true in a comparatively new field such as reliability, in which it is important to be conversant with the progress being made by others. The first part of this paper discusses the classification of documents, and their cataloging to enable location by name of sponsoring organization, author, title, or subject. The controlling of catalog operations is described.

In the second part of the paper an example of the classification and cataloging of an article is presented. The author's complete reliability classification system is given, together with a relative index, listing topics alphabetically and citing their classification numbers, and finally, a list of subject headings.

REVIEW: As the author has stated, an efficient system for handling reliability documents is important to an effective reliability program. The system described in this paper reflects a great deal of thought and effort, and undoubtedly meets the needs for which it was designed. However, opinions differ as to the needs, in terms of level of detail, which an information retrieval system must meet, and the perfect system is yet to be devised. A system in widespread use in the Reliability and Quality Control fields is the ASQC Literature Classification System, which is used in coding papers in RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS. Unfortunately the codes in the classification system described in this paper are assigned entirely different meanings, as compared to the ASQC system, so that one could not use both systems without confusion; or convert from one to the other without completely tearing out an existing filing system. It would seem better, therefore, to have devised an expansion of a system already widely used than to set up an entirely new and different system. A code system incorporating the existing one, but expanding it to meet the needs of a greater level of detail in information retrieval, would have been, indeed, a significant contribution. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1620
Codes 612;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Flight simulation--a reliability shortcut (reliability mathematics corner)

AUTHOR: V. C. Brown, Supervisor, Reliability Computations, Chrysler Corporation, Space Division

SOURCE: Evaluation Engineering, vol. 3, March/April, 1964, pp. 28-29

PURPOSE: To point out that logic equations can be written for a system and evaluated by Monte Carlo runs on a computer.

ABSTRACT: A set of Boolean logic equations can be written for a booster system and put into a computer. Also into the computer can be put the failure rates of the parts. The computer can then be programmed to simulate flights with failures occurring randomly. The success/failure of each flight is determined, together with what caused the failures.

REVIEW: This does not appear to be a new method of analysis although it is certainly useful in some situations. The situations are limited to those in which good/bad is an adequate description for the performance of each <u>part</u>. While good/bad is an essential description of <u>system</u> performance in the conventional reliability context, it can happen that two or more parts may interact in such a way that one compensates for another in the system output. Thus good performance of each and every part is not always essential to good performance of the system.

The paper is quite brief and will serve largely to bring the method to the attention of those not otherwise familiar with logic equations and Monte Carlo simulation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1621
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: "Reliability" -- outdated?

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 3, March/April, 1964, p. 31

PURPOSE: To report on a discussion at a seminar.

ABSTRACT: Has the word "reliability" been beaten to death in the electronics industry? This important question was raised at the Fourth Annual Semiconductor Specialists Seminar. G. A. Hildebrand answered the question in this way, "The word 'reliability' has been misinterpreted. Reliability should not be tested into a product but built into it."

Another suggestion was that "manufacturing capability" be considered as a replacement for "reliability." Although no concrete conclusions were reached, it was agreed that in some cases the word "reliability" is used improperly.

REVIEW: The title is somewhat misleading since the essence of the short article, insofar as reliability is concerned, is quoted above. The word reliability is rarely misused in technical articles any more; it is, however, beaten to death in many advertisements.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: New transistor failure mode created by tests

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 2, November/December, 1963, p. 16

This is an editorial summary of the important points in the paper covered by Abstract and Review Serial Number 1457.

TITLE: 10th Reliability Convention goes international

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 3, January/February, 1964, pp. 9, 10, 12, 32

This report consists of abstracts of some of the technical papers presented at the Tenth National Symposium on Reliability and Quality Control.

TITLE: Special Reliability Convention report

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 3, March/April, 1964, pp. 6-8, 10, 12

This report describes the new Air Force Parts Reliability Program and presents abstracts of some of the technical papers presented at the Tenth National Symposium on Reliability and Quality Control. The technical papers on reliability presented at this symposium have been covered by Abstracts and Reviews Serial Numbers 1179-1190, 1191-1205, and 1266-1293. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1623
Codes 711;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Solderless wrapping of pigtail components

AUTHOR: R. H. Van Horn

SOURCE: Bell Laboratories Record, vol. 41, pp. 415-418, December, 1963

PURPOSE: To discuss the solderless wrapping of electrical connections.

ABSTRACT: The solderless wrapped connection originated as an economical way of connecting switchboard cable to the terminals of wire-spring relays. New uses for it came about with the military requirement for a highly reliable method for connecting pigtail leads of resistors, capacitors, transistors, diodes, etc., to fixed terminals. Many component pigtails are now being solderless wrapped, some by automatic machines. In the early applications the wrapping wire was always soft-drawn copper in gauges 20 through 26; now other materials are frequently used. Some pigtails are gold plated but various grades of brass, hard coppers, and nickel are also used. A soft gold finish was used originally on all terminals, but recent tests have shown good results with electro-tin finishes which are more economical.

Usually the wire is wrapped onto terminals with a square cross-section 0.045" by 0.045". This cross-section offers the highest electrical stability of all those previously standardized for telephone applications. The number of turns of wire varies with gauge, being fewer as the diameter is increased, and ranging from three for 18-gauge wire to as much as six for 25-gauge wire.

The reliability of a particular wire-and-terminal combination in solderless wrap is defined as the probability that less than a stated fraction, such as one in ten thousand, of an original population of connections will exceed a specified electrical resistance during the normal life of the connection. Some early observations on large samples indicated that the logarithms of measured resistance values were distributed almost normally. A better approximation was found by fitting the characteristics of the logarithms (base 10) of the measured resistances in tenths of milliohms to a Poisson distribution forming what might be called a log-Poisson distribution.

REVIEW: This is an interesting, factual account of the solderless wrapped connection. Although the paper would be readily understood by the average high-school senior, it could be read with profit by many Ph.D.'s--in particular those who complain about the lack of research on the interconnection problem! Telephone companies in general have a bigger interconnection problem than any other industry; on the whole, they obtain remarkably good results. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1624
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability of electronic components remains a problem

AUTHOR: --

SOURCE: Translation of an unsigned article in the Russian-language newspaper Ekonomicheskaya Gazeta, Moscow, 2 March, 1963, pp. 10-11; in USSR Industrial Development, Soviet Precision Equipment, No. 67, DDC AD No. 405207; OTS: 63-21560; JPRS: 18, 654, 11 April 1963

PURPOSE: To discuss some aspects of the problem of reliability of electronic components in the USSR.

ABSTRACT: The requirements of the national economy (of the USSR) for electro-vacuum devices are not being met in terms of quality or quantity. The problem of reliability is complex and can be resolved only through the collective efforts of related branches of industry. Equipment used in the manufacture of electronic products should not be made by the electronics industry but be designed and made by the committee on automation and machine building, since in machine building a rigorous theory of tolerances and a theory of interchangeability were elaborated long ago.

It is pointed out that the problem of reliability is also associated with that of obtaining high-purity materials. Only a thorough knowledge of the physical foundations of modern electronic devices enables the design engineers to select operating conditions, to design circuits rationally, and to assure all conditions for the reliable functioning of electronic devices and pieces of radio equipment as a whole. Various examples are given of certain radio tubes working reliably in one type of TV set while being unreliable in another. It is maintained that plants in the USSR should condition their TV sets for several hours in order to ascertain which electronic components show a change in characteristics -- at present, defects are discovered only after purchase by the consumer.

The need is noted for non-contact control systems based on transistors or magnetic cores. The chief advantages offered are static sensitivity, plus the absence of moving parts, with no mechanical wear. There is also a need for the mass production of 'trinistors' which make possible the direct control of large-capacity electric motors.

REVIEW: Apparently, this translation from a Russian language newspaper is a report of a meeting of "experts" on the reliability of radio-electronic systems. There is little of technical interest in the report. However, the reader obtains a fascinating glimpse of bureaucracy at work behind the Iron Curtain. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1625
Codes 822;840;873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Use of failure statistics in design

AUTHOR: Walton B. Bishop, Physicist, Solid State Sciences Laboratory, Air Force Cambridge Research Laboratories, Bedford, Massachusetts

SOURCE: Electro-Technology, vol. 72, July, 1963, pp. 97-99 (DDC AD No. 433596 is a reprint of this article)

PURPOSE: To advocate periodic replacement of parts before the onset of wearout failure.

ABSTRACT: Parts (the term is used in a general sense) have three failure periods: infancy, constant-hazard, and wearout. If the time to onset of wearout is known for the parts that will wear out first, they can be replaced before failure. Parts with much longer times to onset of wearout can sometimes be replaced with parts having shorter lives, all to the advantage of the system.

REVIEW: This article uses some of the ideas presented in the papers covered by Abstracts and Reviews Serial Number 784, 785, and 1173 (all by the same author). The basic idea, presented in the above ABSTRACT, has merit, but the paper tends to be unduly long and involved to make the point. There is some confusion about MTTF; it is used to apply to the wearout period and not to the constant-hazard period. The simple failure probability density function (-dR/dt) seems to be confused with the hazard function $(-\{dR/dt\}/R)$ in some of the curves. Much of the mathematics is unnecessary for the main thesis. It is not even necessary to know the failure probability density function in the wearout region. One need only know the approximate time of its onset.

Many parts in use in electronic gear appear to have an onset of wearout sufficiently in the future to be undeterminable; in fact, some pieces of equipment have this property for all practical purposes. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1626
Codes 711;782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The nature of materials failure under space conditions

AUTHORS: (Staff report based on a paper by S. M. Skinner, W. J. Lytle and J. W. Merck, Westinghouse Air Arm Division, presented at a symposium "Dielectrics in Space," held at Westinghouse Research Laboratories, June 25 and 26, 1963)

SOURCE: Electro-Technology, vol. 72, September, 1963, pp. 128-132

PURPOSE: To discuss the factors affecting materials failure under space conditions.

ABSTRACT: Space environment effects which have been found to be complex and even obscure in nature include space vacuum, fluctuating temperatures and magnetic fields, internal frictional contact between materials, and the accumulation within an enclosed environment of trace amounts (or more) of gaseous products which cannot practicably be removed. These effects are discussed in some detail.

The measurement of failure effects in dielectrics requires relatively thorough study of the dependence of the relevant characteristics upon temperature, frequency, and chemical environment. Other methods which may be used include various X-ray and polarized-light techniques, magnetic measurements, and the effects of surface adsorption upon the density of unpaired electrons, annihilation of positrons in materials, and electron-beam methods.

Other effects which are discussed include the effects of electric fields on tensile properties, fatigue resistance, repeated-contact charge transfer, electrical effects on adhesion, surface-charge mapping, stick-slip and charge transfer, photovoltaic effects, and electrical hysteresis curves.

REVIEW: This excellent paper is packed with interesting information. There is a bonus of 13 cited references. Although the paper does not deal explicitly with reliability per se, it can be considered to be essential background reading for the well-informed reliability engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1627
Codes 782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Problems in insulated wire and cable in space-vehicle systems

AUTHOR: H. S. Adams, Materials Technology Department, Hughes Aircraft Company

SOURCE: Electro-Technology, vol. 72, September, 1963, pp. 133-136

PURPOSE: To discuss the types of insulated wire and cable suitable for use in space-vehicle systems.

ABSTRACT: Insulated wire and cable are indispensible to the reliable operation of virtually every element in the electrical/electronic systems of space vehicles. Selection of wire and cable for aerospace applications must take into consideration functional requirements as well as environmental factors.

Functional requirements can be considered in three classifications: signal, power, and radio-frequency. The limiting factor in signal-lead insulated wire selection is adequate physical strength for reliability; wire size should be based on this consideration. The most vulnerable point is the interface between the conductor and connector pin. Power-lead size selection must employ de-rating factors because there is no heat transfer by atmospheric conduction or convection. Coaxial cables do not usually present any problems.

The most severe environmental hazards are encountered by wires in external harnesses, for which temperatures can range from -185°C to 125°C and the pressure is less than 10^{-9} torr. Solar and sometimes Van Allen radiation are present; severe vibration can always be expected. The outgassing of condensable fractions is another condition which must be considered as inimical to reliability. Internal wiring harnesses are exposed to less severe environments. Thermal controls are often employed to minimize temperature extremes. Encapsulation provides good protection against vibration, shock, and handling hazards.

For external harness applications, stranded copper-alloy conductors are recommended, since their use permits substantial weight economy. No conductor should be smaller than AWG 24 with copper alloy, AWG 22 with pure copper. Polytetrafluoroethylene (TFE fluorocarbon) is the best all-round wire insulation for aerospace use.

REVIEW: This is an informative paper which conveys a maximum of information with a minimum of words. There is a short bibliography, devoted mainly to articles on space environments. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1628 -1
Code 782

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effect of temperature on life of carbon-composition resistors

AUTHOR: George McKnight, Speer Carbon Company, St. Marys, Pennsylvania

SOURCE: Electro-Technology, vol. 72, September, 1963, pp. 208,210

PURPOSE: To discuss the effect of temperature on the life of carbon-composition resistors.

ABSTRACT: Tests made in the quality-control laboratory of the Speer Resistor Division of Speer Carbon Company have indicated that the effects of operating temperatures upon carbon-composition resistors can be estimated with some accuracy using the rule that lowering the temperature by 10 deg C halves the degradation rate.

The empirical Arrhenius equation

$$d \ln k/dT = A/RT^2$$

was derived from investigation of the energy of activation of chemical reactions. This equation in most cases expresses the relation between the specific reaction velocity k and temperature. T is the absolute temperature, R is the gas-law constant, and A is an energy-quantity characteristic of the reaction which is commonly termed the energy of activation.

Over wide temperature ranges the value of A usually diminishes somewhat. However, for the majority of homogeneous reactions it is usually relatively satisfactory to assume that A is a constant, in which case the equation integrates to

$$\ln(k_{t2}/k_{t1}) = A(1/T_1 - 1/T_2)/R.$$

If A is relatively constant, a plot of ln k vs 1/T gives a substantially straight line of slope -A/R and is a convenient method of representing reaction-velocity-temperature data.

The Arrhenius equation is explained by the idea that in every system an equilibrium exists between normal and "active" molecules, and that only the latter can take part in a chemical reaction. Increases in temperature therefore increase the velocity of a chemical reaction, and for a homogeneous process the velocity constant is approximately doubled or trebled for each 10-deg C rise in temperature. This phenomenon has come to be known as the "10-degree rule."

Chemical changes taking place as a result of the heat have long been considered the cause for resistance changes in carbon-composition resistors under load tests. The degradation rate of such resistors should therefore follow Arrhenius' equation, giving a straight line plot when the logarithm of the degradation rate

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

is plotted against the reciprocal of the absolute temperature.

Speer has employed the findings based upon Arrhenius' equation and has used the rule to estimate the effect of ambient temperature and load derating upon the life of its 1/2-watt resistors.

Heat-stability tests were also conducted for 1000 and 2000 hr, and at 130, 150 and 195 C. All showed that the 10-degree rule was followed very closely. (Author)

REVIEW: The important information here is "... the effects of operating temperatures upon carbon resistors can be estimated with some accuracy using the rule that lowering the temperature by 10°C halves the degradation rate." However, an average change by a factor of 1.5 rather than 2 in degradation rate would seem to be a much more reasonable estimate over the temperature range. In any particular 10°C range, the factor may be as high as 2 or as low as 1 (in one case, it is even less than 1). Since each data point is the average of ten resistors, the curves should be reasonably good (ignoring experimental error, no estimate of which is given).

In a private communication the author has commented as follows: "This conclusion by the reviewer can be obtained only by taking the slope of certain lines between closely spaced points giving results that are obviously the result of small experimental inaccuracies, such as comparing the results obtained on 10K resistors at 150°C and 160°C. Here the lower change at 160°C is clearly NOT true of the actual rate of degradation as the remaining data shows, but is the result of an error of about 1/2% or 1% in the experimental data." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1629
Codes 824;844

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

TITLE: Mortality curve for galvanometers

AUTHOR: V. Tarbell, General Electric Company, Huntsville, Alabama

SOURCE: ISA Journal, vol. 10, August, 1963, p. 79

PURPOSE: To describe a method of predicting the mortality rate for galvanometers.

ABSTRACT: As part of a larger study of galvanometer availability, replacement, and reliability, it was necessary to determine whether galvanometers have a critical period during which they are likely to fail. To do this, many studies were made. However no meaningful correlation could be found between the many incidents recorded. During the six-year period recorded, there had been accidental overloads to oscillographs that destroyed as many as 36 galvanometers at one time, both large and small purchases had been made at irregular intervals, and transfers from one area to another had been made in large and small quantities.

This lack of pattern seemed to parallel human life in its exposure to accident, disease, and migration. It is suggested that an approach similar to life insurance premium calculations could be made. For these calculations, the life history of any particular group is not necessary. Instead, each age group is studied separately and the probability of death at any age found, or more pleasantly and precisely, the probability of surviving each year can be determined.

The principle of the human mortality chart has been utilized to construct a galvanometer mortality curve in which the probability of a galvanometer giving S months of service is plotted as a function of S. (Author in part)

REVIEW: This is an interesting concept which might also be applied to other items of equipment in quantity use. However, attempts to use this method for small populations of galvanometers (or human beings) could give some highly inaccurate forecasts! ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1630
Codes 782;833;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Phosphors trace heat flow patterns

AUTHOR: (Editorial Matter based on a talk given at WESCON, August, 1963 by H. D. Frazier, Pacific Semiconductors Inc., Lawndale, California)

SOURCE: Electronics, vol. 36, August 23, 1963, pp. 40-42

PURPOSE: To describe a new technique for studying the heating of electronic components under load.

ABSTRACT: A technique has been developed to study heat-effects in electrical components under load. The method combines the use of temperature-dependent fluorescent paints with motion pictures taken with ultraviolet light. The surface to be studied is coated with a thin film of phosphor pigments that are dispersed in ultraviolet-transmitting paints. A short motion picture is taken under ultraviolet floodlights, while the pulsed-power applied to the circuit is increased to successively higher levels with just enough time between pulses to observe the rate of recovery due to interim cooling.

Using this technique, various phenomena related to temperature distribution can be observed. By watching the way in which the heat-distribution pattern deviates from the usual one over a short period of time, temperature gradients can be analyzed in minute detail.

Four thermographic phosphors are used which cover an entire temperature range from 25°C to 400°C. One phosphor is sensitive between 25°C and 70°C and has an approximate sensitivity of 25% quenching per degree C.

The total cost of setting up apparatus to examine a large number of phenomena or devices can be less than $100.

REVIEW: This new technique would appear to simplify the problem of analyzing component failure due to heating effects. Like the measuring of infrared radiation intensity and the detection of RF noise (see Abstracts and Reviews Serial Numbers 626 and 627), it is a technique which has considerable potential usefulness in dealing with electronic components and circuitry. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1631
Codes 770;782;815

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failures spark work on standard tests for space equipment

AUTHOR: --

SOURCE: the magazine of standards, vol. 34, pp. 207-208, July, 1963

PURPOSE: To direct attention to the formation by the American Society for Testing and Materials of Committee E-21 on Space Simulation.

ABSTRACT: The American Society for Testing and Materials, noting the fact that a number of failures in the USA's space effort have been due in large measure to poor qualification testing has declared: "These costly failures have clearly indicated the need for reliable standard test methods."

Acting on this principle, ASTM has organized a new committee, E-21 on Space Simulation. Rigorous requirements and methods for qualifying materials, components, and vehicles to be used in space will be developed by this committee. Five subcommittees will do the preliminary work and are designated as follows:
Subcommittee I, Executive Subcommittee
Subcommittee II, Nomenclature
Subcommittee III, Test Methods
Subcommittee IV, Simulation Requirements
Subcommittee V, Liaison.

It is noted that some 14 ASTM committees have interest in this area as do a number of other national societies and associations, and the U. S. Government. Official liaison representation has been arranged with the American Standards Association, American Vacuum Society, Institute of Environmental Sciences, as well as unaffiliated groups in this field of interest.

ASTM invites all persons interested in contributing to the work of Committee E-21 to contact Eugene N. Borson, Aerospace Corporation, P. O. Box 95085, Los Angeles 45, California.

REVIEW: This is a straightforward statement outlining the fact and functioning of the committee and its subcommittees. Both Subcommittees III and IV have a number of sections charged with specific areas of interest. Activities of this sort are expected to aid the reliability effort materially. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1632
Codes 711;782;835

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Encapsulating to military specifications

AUTHOR: Frederick L. Koved, Engineering Supervisor, Magnetic & Transformer Group, GPL Division, General Precision, Inc., Pleasantville, New York

SOURCE: Electronic Industries, vol. 22, July, 1963, pp. 92-96

PURPOSE: To discuss the considerations which must be reviewed by the systems engineer before specifying encapsulation processes.

ABSTRACT: The need for reliable electronic components has spurred the development of encapsulation systems to meet military specifications. Encapsulation is also used in equipment for lightweight, dense packaging needs of the missile age. A typical material now available is silicone casting resin. This is a tough, transparent, repairable material for encapsulating a printed circuit assembly. Casting resins can be used in conjunction with suitable fillers to increase thermal conductivity. To give dimensional stability, and to provide a protective coating, preformed resin shells are often used.

Designers must take into account environmental, electrical, mechanical, and chemical requirements when specifying encapsulation processes. The cost of the system should be carefully reviewed in the early stages of design. Environmental considerations are discussed in detail with reference to the appropriate military specifications.

REVIEW: Encapsulation has an important bearing upon component reliability. A more descriptive title for this paper would have been "How to encapsulate." It appears to be directed at the technician rather than the systems engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1633 -1
Codes 824;837

844

612;837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: A discipline emerging from the shadows

AUTHORS: An Electronic Design Special Report
Robert H. Cushman, Technical Editor

SOURCE: Electronic Design, vol. 11, November 8, 1963, pp. 38-40, 42-52, 54-57

This report consists of the three parts which are considered separately below.

SUBTITLE: Choosing the best method for a variability analysis

AUTHOR: Donald G. Mark, Battelle Memorial Institute, Columbus, Ohio

SOURCE: As listed above, pp. 39-40, 42-49

PURPOSE: To review two advanced methods of variability analysis and to compare them with two standard methods, all as applied to an elementary voltage divider circuit.

ABSTRACT: There are five primary methods of circuit variability analysis: the worst case, the two-at-a-time parameter variation, the moment, the Monte-Carlo, and the empirical methods. The first four are mathematical, the last is a breadboard technique not further discussed in the article. Worst case analysis has as its objective the determination of the possibility of failure; two-at-a-time analysis seeks to establish realistic tolerance limits for parameters; and the statistical moment and Monte-Carlo methods give reliability estimates.

Worked examples demonstrate that no one of the methods can give a completely satisfactory solution. The moment and Monte-Carlo approaches require additional statistical data on the variability of components, including mean value, standard deviation, normalized standard deviation and variance, and, where called for, the correlation coefficient between related parameters; but they in turn yield much more information about the circuit.

REVIEW: The model chosen to be analyzed with its five parameters is on the one hand simple enough to comprehend in an intuitive fashion while at the same time offering enough complexity so that the analysis does not become trivial. Enough detail is given for each of the solutions so that the serious reader can bridge the gaps with reasonable effort. An exception to this is the Monte Carlo method which requires the use of a computer to completely follow and understand its detailed workings.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

SUBTITLES: Reliability: Failure sleuths at work
Reliability: Looking inside solid-state devices

AUTHOR: --

SOURCE: As listed above, pp. 50-52

PURPOSE: To present pictorial features to accompany a special report on reliability.

ABSTRACT: This item consists of two pictorial layouts. The first is a series of eight photographs and accompanying captions over a two-page spread following the steps in determining the cause of failure in a logic module. Highlights include an X-Ray photograph of the module, probing of a sectioned diode with micromanipulator probes, and a photomicrograph showing the cause of failure, a 600 micro-inch-thick gold-silicon alloy channel.

The second feature is a pair of photographs of a microcircuit as displayed on the face of a cathode ray tube when an electron beam is used to scan the circuit. Light and dark areas appear depending on the potential of the surface being scanned. A breakdown in the collector-isolation area junction becomes readily apparent through the use of this technique.

REVIEW: These are interesting pictorial features, although they are not directly related to the accompanying articles in the report. The first feature is sufficiently self-explanatory but the second one raises more questions than it answers, and fails to adequately designate a suitable source of further information. This in spite of the fact that an enlarged portion of one of the photographs was deemed unusual enough to comprise the cover of the issue.

SUBTITLE: How a Monte-Carlo analysis optimized a circuit

AUTHORS: E. Parascos and L. Pabian, Kearfott Division, General Precision Aerospace, Little Falls, New Jersey

SOURCE: As listed above, pp. 54-57

PURPOSE: To show how a Monte-Carlo analysis can locate out-of-tolerance situations not revealed by worst-case design.

ABSTRACT: The reliability engineer must go deeper into the analysis of a circuit than the circuit designer usually does if he is to avoid merely repeating the calculations the circuit designer has al-

ready made. A computerized analysis technique such as the Monte-Carlo statistical approach is such a method.

A gain-of-10 amplifier for a high-reliability military missile program was designed by worst-case techniques, and then analyzed by the Monte-Carlo technique. A master gain equation was written and then random values of each of the parameters within specified tolerances were generated by the computer, inserted into the master expression and the gain determined. A histogram of 134 such runs showed that a significant number fell below the minimum gain specified. The Monte-Carlo method itself is unable to define the critical parameters. A numerical differentiation whereby each of the 14 parameters was changed in turn by 1% showed that the output impedance of the first-stage transistor and the resistances of two resistors had the greatest effect on gain. Reducing one resistor value by 10% brought the distribution of values at the 3σ limits well within tolerance.

Cost estimates for Monte-Carlo analysis are presented in the form of time requirements for first and successive runs.

REVIEW: The approach taken in this paper is rather unsophisticated, but the paper is useful in attracting attention to a powerful tool. Gaussian distributions of component part values are assumed, although it is noted that experience might show that other distributions are more valid. The equation for the Monte-Carlo selections process for the random value of the parameters is stated but not justified. The circuit itself has some anomalies and the master gain expression ignores the transistor reverse voltage gain. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1634 -1
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Transistor flip-flops--worst-case design is your best bet.

AUTHORS: William Roehr and James Kane, Motorola Semiconductor Division, Motorola, Inc., Phoenix, Arizona

SOURCE: Electronic Design, vol. 11, November 8, 1963, pp. 58-60, 62 (Part 1), November 22, 1963, pp. 54-59 (Part 2), December 6, 1963, pp. 60-63 (Part 3)

PURPOSE: To establish an organized procedure in designing flip-flop circuits for relating parameter and power supply variations to specified triggering and loading conditions.

ABSTRACT: Expensive overdesign and/or marginal design of flip-flops can be avoided if "worst-case" conditions are taken into consideration. Transistor, power supply and resistance tolerances must be included in the early stages of the design procedure to insure meeting the specified output conditions and to utilize to the fullest a given transistor's characteristics.

In the preliminary design stages expressions for maximum and minimum values of collector current are obtained in terms of the appropriate maximum or minimum values of the load currents, load voltages, and supply voltage.

Low ratios of collector to load current (and output voltage to supply voltage) permit the use of low-β transistors but make the output voltage a sensitive function of the load resistance. Output voltage stabilization can be achieved by using clamp diodes. The use of clamp diodes to limit the excursion requires that the effective load current be increased slightly to keep the diodes in conduction. Other than this, there is little change in design considerations.

Part 2 of the article sets forth a step-by-step design procedure using 1% and 5% initial tolerance resistors with 1% tolerance on the power supply in both cases. Worst-case end-of-life limits of 5% and 20% are assumed in the calculations. Using the 5% initial tolerance resistors, the maximum collector current is nearly doubled, and the maximum base current is more than doubled over the case for 1% initial tolerance resistors. The temperature extremes chosen are -55^{o} and $+85^{o}$C.

Part 3 presents an optimum method of triggering and relates the effect of component values to waveshape. The recommended circuit utilizes pairs of triggering and charging diodes with associated resistors and capacitors. The resistor shunting the triggering diode has conflicting requirements; it should be high in value for short fall time, but low in value to improve the triggering action.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Values of two to four times the cross-coupling resistance are about optimum.

REVIEW: The article is seriously marred by bad typography, particularly in Part 1 in which, for example, identical expressions are given for both maximum and minimum values of supply voltage. The subscript on n in the expression for minimum R_c should be an R, and a bar should appear over I_c' in Equation (2), etc. The article is over-condensed, possibly as a result of poor editing rather than poor writing.

The splitting of the article makes it necessary in following the step-by-step design procedure of Part 2 to continually refer to the previous part which had appeared two weeks earlier. Added to the confusion is a shift in notation for β and a vagueness about some of the terms. A proper understanding of Part 3 would require the availability of a previous article by one of the authors. A footnote on page 63 of Part 3 defines charge in terms of the time only, omitting the current factor.

In spite of the flaws noted above, most of which appear to be of an editorial nature, the article does offer a number of sound observations on the design of flip-flops as well as one of the more straight-forward procedures for worst-case design. While there are many situations in which worst-case design is an excellent idea, sometimes it may not be. It should always be kept in mind that the system should be optimized with respect to system requirements--not circuits with respect to "arbitrary" circuit specifications.

In a private communication, the second author has indicated that the following typographical errors have been observed:

(a) on p. 59 of Part 1, $\beta*/2$ should be $\beta/2*$ since the asterisk calls attention to the footnote and is not part of the equation.

(b) on p. 55 of Part 2, under the example step 6 $\overline{SV_{CE}}$ = 0.23v@ β_F = 18 and T_J = 85°C should be T_J = -55°C.

(c) on p. 60 of Part 3, 2nd column, last paragraph Q_T should be Q_C since the charge refers to the charge on C_T.

(d) on p. 62 of Part 3, Table 1, the last column should be labeled t_{total}. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1635
Code 870

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Maintainability
The other side of the reliability coin
Mil specs pinpoint maintainability goals
New ammunition for trouble shooters
Making the best use of design reviews

AUTHOR: David A. Findlay, Technical Editor

SOURCE: Electronic Design, vol. 11, December 6, 1963, pp. 38-40, 42, 44-52

PURPOSE: To survey a few highlights of maintainability.

ABSTRACT: Maintainability is in the infant stage in which reliability was during the early 1950's. Maintainability is important because system effectiveness is made up of mission reliability, operational readiness, and design adequacy; maintainability is part of availability, which is part of operational readiness. (Some definitions of terms are given.) It is important for the designer to consider the ease of maintenance and to plan for it. There are many ramifications such as plug-in modules (what size?), throw-away units, repairable units (at what level?), and required technician training. Check lists for considering all the factors are almost essential and an example is given. Trade-offs can be made between cost, reliability, etc.--these too are difficult. The Air Force document MIL-M-2651C explains in considerable detail much of the requirement for and means of checking a maintainability specification.

Automatic checkout systems can be used, although here again the advantages and disadvantages must be weighed. Semiautomatic systems are also being developed. Two of these are explained. The design review is an essential step in any design where the penalty for "small" mistakes is high. A very short check list is shown as an example and several maintainability references are given.

REVIEW: This article fulfills the stated purpose well. There are obviously many topics not covered, and the ones discussed are touched only lightly. It is useful mainly as an introduction to the subject.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1636 -1
Codes 800;811;812;
813;820;838;
841;844;850

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability: motives and methods (in five parts)

AUTHOR: Joseph Movshin, Management Consultant, St. Louis, Missouri

SOURCE: Quality Assurance, vol. 3, January, 1964, pp. 18-22, (Part I), February, 1964, pp. 39-43 (Part II), March, 1964, pp. 33-37 (Part III), April, 1964, pp. 31-35 (Part IV), and May, 1964, pp. 41-46 (Part V)

PURPOSE: To present a series of articles on various aspects of reliability.

ABSTRACT: Part I: Chronicle of Innovation

The older attitudes on the causes of equipment failure were based on the following two concepts:

(1) Each assembly has a "weakest link" which provides the opportunity for failure. Reliability improvement can be achieved by locating and strengthening the "weakest link."

(2) Random failures are caused essentially by failure to accomplish the design specifications in production or use activities. Failures are, in effect, due to "out of specification" conditions for "good" designs.

By contrast, modern failure concepts include the following:

(1) Objective probabilities of failure exist for each component and design. These are the inherent results of design, manufacturing, and use factors.

(2) Each assembly and component experiences failures in accordance with its own inherent probability of failure, or failure rate. The number of failures can be reduced by design, manufacturing or operational changes which alter the basic elements of influence on the system.

The cost of failures is cited as an important motivating factor in early reliability studies. The purposes of the various task groups in the Advisory Group on Reliability of Electronic Equipment (AGREE) are outlined. The spheres of interest of reliability and quality control are contrasted.

Part II: Measuring Reliability

The parameters of reliability have been developed as modern engineering tools because of the need to accomplish two fundamental objectives:

(1) To provide measurements of that elusive characteristic of all equipment called "life" or "performance".

(2) To provide economical means for predicting and improving the life/performance characteristic.

To accomplish these goals, statistics are used to provide the basic measures, and engineers then use the measurements to identify and improve factors adversely affecting life or performance. The concept of failure probability is discussed. The "bathtub" curve depicting failure rate as a function of time is described. The

exponential reliability function is introduced, and the role of the chi-square distribution in calculating confidence limits on MTBF is illustrated. Brief reference to maintainability and availability is made.

Part III: Data Collection
The reliability of an assembly or system is dependent upon the individual failure rates of its components. Generally, a new design is the result of a unique arrangement or combination of established and new components. Failure data may be obtained from:

(1) Published references, including technical articles, suppliers' literature, and government agencies.

(2) Research test programs, which may include life tests to develop basic data for a manufacturer's own product, or for the special components used therein.

(3) Operational (historical) reports, field service data, or a special program for collecting information on operating time and failures.

Test limitations and alternatives are considered. The use of derating factors is illustrated. The role of block diagrams is indicated for identifying systems in which units are logically in series, those in which units are logically in parallel, and situations in which conditional probabilities apply. Brief reference is made to component analysis, failure analysis, and safety analysis.

Part IV: Reliability Improvement
The basic purpose of a reliability program is to obtain measures which assist in improving product reliability. Two principal concepts of improvement have been suggested:

(1) Improvement of the inherent reliability of equipment as designed.

(2) Improvement of the end product, or the "as-built" or "as-installed" reliability.

A well-balanced reliability program should take both of these concepts into consideration. The two general approaches to reliability improvement result in these three specific types of reliability improvement programs:

(1) Prevention of degradation.
(2) Upgrading of components.
(3) Improvement of design.

In this order, they represent the progressive stages of sophistication in reliability improvement. Each of the three types is discussed. Factors important in preventing degradation are good communications, the application of human engineering principles, the control of process and natural variation, and management control. Component upgrading can be achieved by derating, protection, and redundancy. Design improvement is effected by

identifying sources of low reliability, and taking appropriate steps to eliminate their causes. Brief reference is made to reliability demonstration.

Part V: Reliability Program Development
The general effects of a reliability program in an organization include:
(1) The necessity for improving quality control.
(2) The demand for greater care and surveillance in manufacturing operations.
(3) The establishment of burn-in and life-test facilities.
(4) Changes in purchasing concepts.
(5) Modifications of the accounting system.
(6) The need for training engineering, management, and operational personnel in reliability concepts and techniques.
Each of these effects is discussed. The approach of management in setting up a reliability program is considered. Cost considerations are described.

REVIEW: This series covers a wide range of topics in a relatively short space. Consequently no aspect is treated in any detail. The papers will be of most interest to the person who wishes to get a bird's-eye view of the subject--notably the newcomer to the field. Some references are cited in each paper for those who desire more details, but the listings are by no means exhaustive.

The only time-to-failure distribution that is considered is the exponential, leaving the implication that it is always valid to assume a constant failure rate (at least for some time period). The failures during this period are referred to as "chance or random," which carries some unfortunate implications, as pointed out in Review Serial Number 1216.

It should also be emphasized that the use of the chi-square distribution in estimating confidence limits for MTBF is tied to the assumption of an exponential distribution of times-to-failure, although the author does not specifically say so. There is also the implied assumption that all of the units involved have the same failure rate. The procedure given is the one which applies when the number of failures is the random variable, and should not be used when unit-hours is the random variable. The omission of pertinent details such as these is a serious pitfall in any attempt to present a brief description of a technical subject. On the technical aspects the reader will do well to consult a competent authority such as Reference 2 cited on p. 43 in Part II.

There is a typographical error on p. 32 in Part IV, viz. the equation in Figure 2C should read: $R_t = R_1(1 + R_s - R_1R_s)$. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Interwoven redundant logic

AUTHOR: William H. Pierce, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania

SOURCE: Journal of the Franklin Institute, vol. 277, pp. 55-85, January, 1964

PURPOSE: To introduce a redundancy theory which unifies many preceding theories, and establishes new and useful circuits.

ABSTRACT: Modern digital computers have their size and capability limited by the reliability obtainable with present technology. The only way in which they can escape the limitations of their components requires the use of theories for constructing arbitrarily reliable computers from unreliable parts, i.e., redundancy techniques.

In interwoven redundant logic, each (redundant) gate receives B versions of each input, and makes its output from the redundant input information. Some (redundant) gates, such as threshold gates and AND-OR-NOT gates, correct errors in one layer. Other (redundant) gates correct errors in two alternating layers. Of these, all-NAND or all-NOR networks automatically have the necessary alternation of layers, while with AND, OR, and NOT networks the alternation must be designed into the network. Both single-layer and alternating-layer error correction schemes correct the most errors when the plan specifying which input signals are connected to which gates is systematic. Restoring organs and quadding are both very special cases of interwoven redundant logic. Interwoven redundant logic is theoretically important because it unifies redundancy techniques, and practically important because it permits error correction in the same circuits which perform logic. Rules and reliability analyses for systematic plans are developed, plans stated, and simple, practical circuit implementations are given. Relevant literature is reviewed and 20 references are cited. (Author in part)

REVIEW: This is an extensive paper which makes an important contribution to the theory of redundancy in computers. As such, it will be of principal interest to the specialist in this field. The reader interested in a good qualitative discussion of the improvement of computer reliability through redundancy should refer to [1], by the same author. Reference [1] includes discussions of the bundle concept, restoring organs, adaptive vote-taking, random and systematic mazes, and threshold gates--all in terms which can be understood by the non-specialist.

REFERENCE: [1] William H. Pierce, "Redundancy in computers," Scientific American, vol. 210, February, 1964, pp. 103-109 ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Integrating spacecraft electronics

AUTHORS: Arnold B. Whitaker and Charles Schuhlein, Grumman Aircraft Engineering Corporation

SOURCE: Space/Aeronautics, vol. 42, August, 1964, pp. 53-59

PURPOSE: To discuss the phenomenon of electromagnetic interference in spacecraft electronics, and to indicate some of the steps which can be taken to minimize its effects.

ABSTRACT: Putting electronics, space vehicles, and launch equipment together without getting electromagnetic interference is not a hit-or-miss proposition; it requires careful analysis and rigorous testing. And the problem of electronics integration will become more challenging as we pack more equipment into spacecraft. Spurious interactions between equipments and environments can cause flight delays and failures. At the same time, possible interferences are not nicely defined.

Many potentially harmful relationships can be isolated by intensive paper analyses on the system design level. As the equipment is put together, the systems integration process tests the validity of analysis at all levels of assembly and acts to uncover any spurious interactions. On the component level, unwanted characteristics can be classified as desensitization or cross-modulation. Desensitization is saturation of one component by another so that the first cannot perform its proper function. Cross-modulation is the unwanted transfer of the characteristics of the current of one component onto another through electromagnetic radiation. Many conventional components have acceptable radiation and susceptibility characteristics. The use of r-f filters, decoupling networks, and component shielding will tend to insure proper performance. Such is not the case, however, for microminiature and integrated circuits, because of their high component density.

The solution to the problem of obtaining knowledge of the interactions of black boxes or assemblies involves radiation and susceptibility tests. These yield information which is then fed into a computer in order to isolate all interactions between radiators and susceptors that could cause malfunction or degradation of a component or system. Modifications as needed are made and electromagnetic compatibility testing is carried out, followed by whatever corrective action may be indicated. Some typical problems that can be encountered are described. These include surges and transients, transients induced by transmitters, the effects of antenna propagation patterns, the effects of the space environment, and interactions between spacecraft and booster.

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

Several pertinent references are cited.

REVIEW: This is a good compact discussion of the problem of electromagnetic interference as it pertains to spacecraft electronics. Its significance from a reliability point of view lies in the role which this phenomenon can play as a cause of degradation or failure of electronic systems. That role will become more acute as progress continues in microminiaturization and integrated circuitry. Thus the subject treated in this paper is one which will become increasingly important to the designers of electronic systems for spacecraft use. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1639
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Studying gross abuse of semiconductor devices

AUTHOR: David C. Porter, Aerospace Division, Boeing Company

SOURCE: Space/Aeronautics, vol. 42, August, 1964, pp. 78-79

PURPOSE: To show that construction defects contribute heavily to present reliability problems with semiconductor devices.

ABSTRACT: Boeing's Physics of Failure group has expended about two dozen man-years in performing several hundred detailed part analyses of semiconductor devices. The results of these studies show that a large number of failures are traceable to (1) abuse by the user and (2) gross defects in the product produced by the manufacturer. The application of consistent failure analysis to unfailed parts revealed irregularities so serious that it was difficult to understand why some devices worked.

The paper includes photographs illustrating some of the irregularities which were found, such as solder voids at critical points, metallic deposits producing intermittent shorts, cathode voids, gas bubble voids, high voltage rejection of zener diode, contacting but non-alloying indium, and burned-out base leads. Some comments are made regarding causes and effects of these irregularities. (Author in part)

REVIEW: The findings reported in this brief paper should be of interest to all users of semiconductor devices. The avoidance of most of these difficulties would seem to necessitate the implementation of a policy of "infinite attention to detail...."

The author, in a private communication, has pointed out that the above is a condensation of [1]. The original paper [1] presents in more detail the results of applying failure analysis techniques to capacitors, resistors, and semiconductors, and includes 18 illustrative figures. It will be well worth the attention of those concerned with the identification of the probable causes of failure of components.

REFERENCE: [1] David C. Porter, "Failure analysis of electronic parts," IEEE Transactions on Aerospace, vol. AS-2, pp. 328-337, April, 1964 ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1640
Codes 770;831

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Titan test experience and reliability engineering

AUTHOR: Robert W. Moyer, Canaveral Division, Martin Company

SOURCE: Space/Aeronautics, vol. 42, August, 1964, pp. 79-80

PURPOSE: To cite some examples of the value of testing as an essential part of the design process.

ABSTRACT: The one-shot lives and extreme reliability requirements of space and missile systems have brought about an increasing emphasis on testing as an essential part of the design process--as opposed to testing as a check on drawing board products. Examples relating to the perfecting of electrical systems are cited from test-design work in the Titan 1 and 2 program.

Proper sequencing of tests has been found to be just about as important as the testing itself. In the experience described, the design could not be considered complete until umbilical drop tests had been made. Checking for stray voltages in ignition circuits for explosive devices--prior to connection of the devices --is extremely important. Abnormalities in one subsystem which adversely affect other subsystems are a source of considerable concern. Not all of these can be detected through testing on the ground. In-flight photographs can be helpful. Design features which, in effect, result in built-in sources of human error must be detected and corrected. (Author in part)

REVIEW: This is a concise description of some experience in the use of testing as a design tool. It should be of interest to design engineers on other aerospace programs, because the basic problems detected and solved are not specific to any one program. Diligence and ingenuity in the search for potential sources of malfunction seem to be the keys to success in this type of effort.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1641 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Quality defects: principal cause of failure

AUTHOR: G. A. Raymond, Univac Division, Sperry Rand Corporation

SOURCE: Space/Aeronautics, vol. 42, August, 1964, pp. 80, 83, 85

PURPOSE: To discuss some inconsistencies in reliability prediction theory and practice.

ABSTRACT: During the past ten or twelve years large sums of money have been spent on developing the techniques of measuring and predicting the reliability of aerospace systems; but many of these techniques are being applied in a "cookbook" fashion, without regard for their limitations and shortcomings. Design and engineering decisions are being based on misapplied reliability criteria.

The concern of reliability engineering should be with decreasing the chance of failure rather than with predicting when and how many failures will occur. It has often been difficult to reconcile certain prediction techniques with the facts observed by designers of electronic equipment. The difficulty is not in the mathematics but in the underlying assumptions necessary to develop the mathematics. One of these assumptions is that each part has a characteristic failure rate for a specific combination of environments. For many types of equipment this is simply not so. The total population of a given type of component used in a system generally consists of two groups: (a) those which are essentially perfect and will have a failure rate of zero during a specified operating time, and (b) those which have some undetected latent defect which will eventually cause a failure. The failure rate as usually calculated reflects the combination of these two groups and is not in fact characteristic of either one. Under the concept which recognizes the existence of the two groups, reliability will improve with time as defective parts fail and are replaced. Screening techniques can be applied to sort out defective parts, thereby decreasing the probability of failure in the population. (Author in part)

REVIEW: This paper appears to be an essay which rather categorically makes a case against much of what passes for reliability engineering, but is in fact inconsequential arithmetic. Taken in that vein, and allowing for some overstatement of the case, the author makes many good points. But if the paper is analyzed point-by-point on a technical basis, the overstatement and categorization no longer serve a useful purpose. Admittedly there is abuse of failure-rate calculations by those who calculate them to four significant figures. However, these failure-rate calculations

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

can serve a useful engineering purpose for "quick and dirty" estimates of the "ball-park" variety. Likewise, most knowledgeable people in the reliability field would not only admit but insist that the reliability of components is a function of who makes them, when, and how. The model of a population being made of perfect parts plus bad ones is applicable in some cases, but certainly not in all. The bland recommendation of screening to remove these bad parts is somewhat akin to that of belling the cat--a good idea in principle, but not so easy to implement. The author does imply, very properly, that there is a lot that can be corrected by "infinite attention to detail," the sine qua non of reliability. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1642 -1
Code 824

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Hazard analysis I

AUTHORS: G. S. Watson and M. R. Leadbetter, Johns Hopkins University and Research Triangle Institute

SOURCE: Biometrika, vol. 51, pp. 175-184, June, 1964

PURPOSE: To present several estimators of the hazard function.

ABSTRACT: Suppose the time to failure, X, of an article is a non-negative random variable with distribution function F(x) and probability density function

$$f(x) = F'(x)$$

everywhere. Then the chance that an article, functioning at time x, will fail in the interval (x, x + dx) is given by h(x) dx where

$$h(x) = f(x)/(1 - F(x)) \quad (0 < x < \infty). \tag{1}$$

The function h(x) is called the hazard or conditional failure rate. If the distribution of X is exponential, mean = $1/\lambda$, then h(x) = λ; for all other distributions h(x) varies with time. In reliability studies, engineers typically envisage h(x) as high initially (x small) due to gross manufacturing mistakes. Then may follow a period in which h(x) is fairly constant, i.e. a period in which failures occur "at random". Then the hazard curve rises as the article 'wears out'. In organisms the first and last phases are due to 'infant mortality' and 'senility'.

Some known properties of the hazard function are summarized. For example it is stated that if X = min (Y_1, Y_2), where Y_1 and Y_2 are independent and are variables with hazards $h_1(x)$ and $h_2(x)$, then the hazard h(x) of X is given by

$$h(x) = h_1(x) + h_2(x). \tag{2}$$

The case for essentially distribution-free estimation of the hazard in engineering reliability studies rests on the following arguments. Such studies may be made to help in the development of a new article or to evaluate the effectiveness of one whose development is complete. In the first situation the need for rapid testing and for an analysis that throws light on the failure mechanism will dominate considerations of the ultimate usage of the article. Now the earlier failures do give an idea of the course of h(x) for small x and peaks in the graph of h(x) do suggest, by (2), that different failure modes be sought out. Thus the hazard function should be very useful here. Since we are dealing with new designs, the distribution of X cannot be known with confidence so distribution-free methods are called

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

for. In the second situation, things are reversed and one will usually be interested in the mean life or the probability of the article working for more than a specified time. These quantities may be increased by giving all articles a suitable 'burn-in' period (see Abstract and Review Serial Number 23). This period intuitively covers the presumed initial peak in h(x) so even here knowledge of the hazard would seem helpful.

Several hazard estimators are listed, including two graphical methods. The properties of the estimators are discussed. Numerical examples are given. Eight pertinent references are cited. (Authors in part)

REVIEW: This is a general discussion of the hazard function and the available methods of estimating it. While the discussion relates to hazard analysis in general, the role of the hazard function in reliability engineering studies is clearly indicated. The paper includes, in part, a clear statement of the precise meaning of the expression "... failures occur at random," which is very often misunderstood by workers in reliability.

The listing and discussion of estimators of the hazard function will be of most interest and value to those with some background in the fundamentals of statistical estimation. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

12/64

Serial Number 1643
Code 821

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A probability problem arising in reliability and traffic studies

AUTHOR: D. P. Gaver, Jr., Carnegie Institute of Technology and Westinghouse Electric Corporation, Pittsburgh, Pennsylvania

SOURCE: Operations Research, vol. 12, pp. 534-542, July-August, 1964

PURPOSE: To discuss the "disappointment time" related to a system which is alternately operative and inoperative.

ABSTRACT: The problem considered in this paper arises in the course of evaluating the performance of a system that (a) is subject to failure and repair, but (b) is used intermittently. Clearly it is pessimistic to evaluate the reliability of an intermittently used system solely on the basis of its "time to (functional) failure," i.e., time to first system failure following an instant at which the system was operating satisfactorily. The reason is that the failure many occur, and be repaired, while the system's function is not needed. Consequently, depending upon the relative durations of failure and repair times as well as system utilization, several failures may occur and be remedied between usage periods before one interferes with system service. To obtain a more meaningful measure of the system's suitability for meeting needs it seems natural to consider the time to system failure during a usage period, or to occurrence of a demand during a system inoperative period, whichever occurs first. Such a time, the 'disappointment time,' measured from an instant at which the system became operative, and denoted by T, is studied under assumptions concerning the usage, and failure-repair, processes which relax somewhat the usual all-inclusive assumptions of Poisson or "random" failures, the Laplace-Stieltjes transform of the distribution function of $T, E(e^{-sT})$, is derived. From this transform an expression for the expected value, E(T), is obtained, and some numerical examples illustrating the dependence of the latter on basic parameters are given. (Author in part)

REVIEW: This is a mathematical paper in which a specific problem is formulated and solved. As such, it is more likely to be of interest to the theorist than to the reliability engineer. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1644
Code 775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nondestructive testing

AUTHORS: Warren McGonnagle, Southwest Research Institute, San Antonio, Texas and Ford Park, Associate Editor (International Science and Technology)

SOURCE: International Science and Technology, no. 31, July, 1964, pp. 14-27

PURPOSE: To present a feature article on nondestructive testing.

ABSTRACT: Nondestructive testing is the use of physical methods for evaluating materials without impairing their usefulness. It plays an important role in a number of industrial manufacturing areas: flaw detection; process improvement, control, and monitoring; measurement of mechanical properties; and the measurement of physical, chemical, and metallurgical properties, as well as changes in them. Nearly every form of energy has been utilized in nondestructive testing. Likewise, nearly every property of the material has served as the basis for some test method. The most widely used of these techniques fit into seven distinct categories: visual, radiographic, thermal, magnetic, liquid-penetrant, acoustic, and electromagnetic. Each method is especially suited for a particular task; hence they do not compete with, but are complementary to one another. All the nondestructive test methods are simple in principle. Success in their use, however, depends heavily upon intelligent application and discriminating interpretation of the results. They are not easily applied cure-alls, but they can be instrumental in assuring quality products if they are integrated into the entire spectrum of manufacturing activity--from design to final inspection.

Each of the above seven categories of nondestructive testing techniques is described in some detail. A number of photographs are included. Reference is made to some of the problems which remain to be solved. Some references in which more details may be found are cited on page 88 in the magazine. (Authors in part)

REVIEW: This is an excellent article for those who wish to get some knowlege of nondestructive testing techniques and their uses. The potential value of these techniques in reliability testing is considerable. There is much room for the test engineer to use his ingenuity in applying good physics in order to obtain desired information.

Articles on nondestructive testing methods which have been covered by RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS are found under Code 775. For example, papers on infrared inspection techniques have been covered by Serial Numbers 626, 941, and 993. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Environmental testing

AUTHOR: Stephen F. Bleich, Associated Engineering Test Laboratories, Los Angeles, California

SOURCE: International Science and Technology, no. 33, September, 1964, pp. 42-44, 46, 48-50, 52

PURPOSE: To discuss some of the problems involved in simulating reality in the environmental test laboratory.

ABSTRACT: Prototype products and simulated realities interacting in the environmental test laboratory constitute an analog computer of enormous capacity. In the course of predicting equipment performance, it may be called upon to handle systems with thousands of degrees of freedom and to generate complex functions many of whose forms are not even known. As problem complexity increases, testing becomes more and more the feasible way to make operational predictions as variables multiply. The important consideration is close approximation to reality. The recognition of this has led to combined environments and most of the other advances in the field. The compromise of reality in favor of uniformity has led to most of the problems and complaints.

The changes in vibration testing during the last few years are outlined. Combined testing involving shock and acceleration together with vibration is discussed. It is pointed out that many specifications emphasize uniformity; in so doing they limit the test engineer and effectively prevent him from conducting a truly realistic test. Tests to simulate exposure to a sea-water/air environment are typically unrealistic in that the solutions used in generating salt fogs and salt sprays are not actually representative of sea water. Similarly there is a need for greater realism in the simulation of temperature-altitude cycling. The result is that there is a tendency for environmental tests to become individual for each project.

REVIEW: Environmental testing plays an important part in reliability demonstration, in evaluating the ability of equipment to perform satisfactorily in its intended environment. The theme of this paper--the need for realistic simulation--is well taken. While the paper does not touch on all aspects of the space environment (e.g. low pressure and radiation are not mentioned), it carries a good message for test engineers concerned with the evaluation of systems for spacecraft use. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1646
Codes 770;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Ball bearing reliability program

AUTHOR: R. W. Constantine, Autonetics, a Division of North American Aviation, Inc.

SOURCE: Proceedings of the Institute of Environmental Sciences 1964 Annual Technical Meeting, Philadelphia, Pennsylvania, April, 1964, pp. 217-224 (Institute of Environmental Sciences, 34 South Main Street, Mt. Prospect, Illinois)

PURPOSE: To describe a reliability program pertaining to a critical component in the guidance package of the MINUTEMAN missile.

ABSTRACT: The concept of the MINUTEMAN missile demands a highly complex yet extremely reliable system. As part of the Autonetics master plan to achieve maximum guidance and control equipment reliability, a major effort was initiated early in the development stages of MINUTEMAN to determine and upgrade the quality and reliability of the three stable platform accelerometers, which comprise the critical sensors of the guidance package. A critical component of the accelerometer is a pair of duplexed ball bearings which must operate continuously at low speeds for several years without servicing or relubrication. This report presents the history of the reliability program in relation to these ball bearings, with emphasis on test equipment, testing procedures, test results, and the steps that have been taken to ultimately ensure that the reliability requirements will be met.

A description of the equipment necessary for precision bearing studies is presented together with the problems of developing realistic accelerated test programs. Life test results are given for bearings using various type ball separators and lubricants. Failure modes are discussed and related to design improvements. Finally, a few practical steps are presented to ensure continued reliability in the production line through the issuance of procurement documents and inspection techniques. (Author)

REVIEW: This is a clear and concise description of the subject test program, including test equipment, procedures, results, and conclusions. Relevant data are presented in graphical form. While this report is concerned with a specific component, the general approach may well have applicability to studies of other components.

A feature of particular interest is the fact that high rotational speed did not accelerate the occurrence of failure as initially expected, and that the reason for this was found. Such a conclusion illustrates the elusive nature of the means of producing a realistic acceleration in the life testing of various components. ##

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Data processing techniques give reality to environmental reliability test results

AUTHORS: J. L. Dunnagan and E. J. St. Peter, Western Electric Company

SOURCE: Proceedings of the Institute of Environmental Sciences 1964 Annual Technical Meeting, Philadelphia, Pennsylvania, April, 1964, pp. 301-304 (Institute of Environmental Sciences, 34 South Main Street, Mt. Prospect, Illinois)

PURPOSE: To describe computerized data-processing techniques for handling reliability test results.

ABSTRACT: Some of the problems which complicate the obtaining and analyzing of reliability test data are the following:

(1) The testing of large numbers of units for long times is expensive.

(2) Large volumes of data in raw form are difficult to comprehend.

(3) Useful and understandable conclusions must be drawn from the test results.

(4) The danger of introducing errors must be minimized.

This paper discusses some techniques used by the Western Electric Company's Environmental Test Laboratory in coping with these problems.

The testing techniques described use automatic data-recording test equipment in conjunction with data-processing facilities. The description pertains to a resistor testing program. The process is completely automatic. A scanner selects the resistor to be measured and connects it to the ohmmeter. When the ohmmeter has balanced, it actuates the card punch to record the correct reading along with the resistor and test identification information. After punching the card, the card punch signals the scanner to select the next resistor and the cycle continues. Each resistor is identified by serial number. The procedures for recording information and checking for errors are described.

For each measurement taken, the percent deviation from initial value is determined. The mean and standard deviation of the test results are calculated. In order to evaluate the effects of environmental conditions, the percent deviations are plotted as histograms. As the test progresses in time, the trends or behavior patterns can be spotted and analyzed. Illustrations are given. Grouped histograms depict the effects of the complete test program. Some extensions of the technique are mentioned.

REVIEW: No doubt most reliability engineers have faced the problems cited in the above ABSTRACT. Thus this paper should be of widespread

interest. The procedure described enables the obtaining of maximum information from the raw data as the test program progresses, thus enhancing its value and effectively reducing its cost. It should be noted particularly that in this process each unit retains its identity through being "tagged" with a serial number, thus enabling the detection of behavior patterns in individual items.

It must be granted that some components are less amenable to the type of test program described in this paper than are resistors. However, the basic principles of efficient data-handling must be applied if realistic and understandable conclusions are to be drawn. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1648
Code 761

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improved reliability through acceptance vibration testing

AUTHOR: Wm. H. Kirk, General Dynamics/Astronautics, San Diego, California

SOURCE: Proceedings of the Institute of Environmental Sciences 1964 Annual Technical Meeting, Philadelphia, Pennsylvania, April, 1964, pp. 545-553 (Institute of Environmental Sciences, 34 South Main Street, Mt. Prospect, Illinois) (See also errata in The Journal of Environmental Sciences, vol. 7, June, 1964, p. 17)

PURPOSE: To discuss acceptance vibration testing as a means of effecting improved reliability.

ABSTRACT: Acceptance vibration testing is a means of detecting latent workmanship defects undetectable by any other practical inspection method, and is best suited for performance on production airborne electronic equipment to improve functional reliability. This test consists of vibrating equipment, while being functionally tested and operated, for a sufficient duration to detect "infant mortality" defects, while expending no significant portion of the equipments' usable life. A complete program for this testing is necessary to determine equipment types to be subjected to this inspection means, for the establishment of test parameters, and for a data feedback system for defect prevention as well as detection. The stimulus, acceleration level, and test duration must be carefully chosen to achieve optimum program benefit.

The General Dynamics/Astronautics approach to this testing program consists of the utilization of a relatively unconventional but effective deterministic vibration stimulus, and test performance on a 100% basis with all critical equipment functional parameters monitored and measured before, during, and after the vibration test. Significant direct end item functional reliability improvement has been realized through performance of this testing. Through the operation of a comprehensive data feedback system, a considerable decrease in problem recurrence has also been achieved. This paper discusses (1) reasons for performance of acceptance vibration testing, (2) test objectives and important test considerations, (3) implementation of an acceptance vibration test program, (4) test parameter establishment, (5) data feedback and test control, and (6) results of the General Dynamics/Astronautics acceptance vibration test program. (Author in part)

REVIEW: This is a rather comprehensive discussion of acceptance vibration testing. The analytical method presented for reduction, comparison, and analysis of vibration data represents an important advance in the determination of maximum permissible acceptance vibration test durations. The utilization of test data for the prevention of defect recurrence is also worthy of note. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1649
Codes 715;782;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Analysis of semiconductor device reliability in radiation environments

AUTHOR: Frank W. Poblenz, The Bendix Corporation, Research Laboratories Division

SOURCE: Proceedings of the Institute of Environmental Sciences 1964 Annual Technical Meeting, Philadelphia, Pennsylvania, April, 1964, pp. 585-591 (Institute of Environmental Sciences, 34 South Main Street, Mt. Prospect, Illinois)

PURPOSE: To consider the influence of nuclear reactor and space radiation on the reliability of electronic components.

ABSTRACT: The Weibull distribution, which is useful in analyzing transistor failures during radiation exposure, has also proved a useful tool in analyzing failures of other semiconductor devices during irradiation. In addition, Weibull graphs show that possible bimodal failures can occur for certain silicon controlled rectifiers and unijunction transistors.

The Weibull plotting technique described in this paper finds its greatest application in the extension of available radiation effects data to low failure probabilities. It enables a designer to select semiconductor devices using failure criteria consistent with a specified reliability and radiation environment.

The conclusions drawn from the transistor, diode, silicon controlled rectifier and unijunction transistor test data are not meant to evaluate the product of any company. (Author)

REVIEW: This paper is an extension of the one by the same author covered by Abstract and Review Serial Number 588. In the earlier paper the Weibull distribution was applied to the analysis of transistor failures during radiation exposure. The extension is to the analysis of performance parameters of other semiconductor devices. An important feature is the prediction of very low failure probabilities as a function of radiation exposure for a specified failure criterion.

Other papers on the effects of the radiation environment on electronic components which have been covered by RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS are found under Codes 715 and 782. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1650
Code 811

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Organization for reliability evaluation in hardware development

AUTHOR: H. A. Campbell, General Electric Company, Re-entry Systems Department

SOURCE: Proceedings of the Institute of Environmental Sciences 1964 Annual Technical Meeting, Philadelphia, Pennsylvania, April, 1964, pp. 609-611 (Institute of Environmental Sciences, 34 South Main Street, Mt. Prospect, Illinois)

PURPOSE: To describe the means of establishing and maintaining a technical organization to operate the reliability function within a development and manufacturing company.

ABSTRACT: Reliability analysis may describe numerically, and is used to predict, the useful lifetime of a product. Life tests of the product and mathematical statistics are needed for the conduct of reliability analysis and predictions. Therefore laboratory facilities and a mathematician are required. The mathematician may be a member of the existing engineering staff, or an experienced design engineer with sufficient mathematical background. Alternatively, a man with prior reliability experience may be recruited, a consultant may be hired to start the activity and train a staff member to handle it, or the whole activity may be subcontracted. Alternatives in setting up a program of valid life-testing include having the tests performed in the quality control department, subcontracting the testing to a commercial laboratory, acquiring the use of government-owned test equipment, or establishing a company-owned laboratory. Some of the considerations involved in the choice of a suitable alternative are discussed.

REVIEW: This paper contributes very little which will not be obvious, even to those with little or no acquaintance with the organization of a reliability function. Assuming that the paper is addressed to the novice in the field, it would have been desirable to cite a more explicit definition of reliability than the one given. Similarly, a "performance rating" is stated without any explanation of how it might be used. Figure 1, mentioned in the text, does not appear in the paper.

The author, in a private communication, has commented as follows. "This paper was invited as a part of a panel discussion on organization and management of environmental laboratories. I attempted therefore to emphasize considerations of organization from the business viewpoint, as the primary subject. In this case, reliability is a secondary subject and is discussed only enough to relate its technological nature to considerations of organization and organization economics." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1651
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability today and tomorrow

AUTHOR: Lt. General Howell M. Estes, Jr., Vice Commander, Headquarters, Air Force Systems Command, Andrews Air Force Base, Maryland

SOURCE: IEEE Transactions on Reliability, vol. R-13, March, 1964, pp. 1-4

PURPOSE: To present the keynote address at the Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964.

ABSTRACT: Reliability is an essential ingredient of today's military systems. It interacts with the product cycle at all levels and places. The required maintenance for many systems costs too much and requires too high skills of too many people. Space systems require a new order of reliability. Most design engineers need some help in the reliability area, especially with the advent of quantitative reliability specifications. There are many Air Force programs to increase, measure, and record the reliability of parts, to probe the physical nature of failures, to look for more effective non-destructive means of checking parts, and to find ways of quickly exchanging necessary information on reliability.

The challenge of space is, for the future, perhaps the greatest. Many concepts must be rethought-through with the problems of manned and unmanned space exploration in mind. However, we will still use many ordinary systems and there is much to improve in them. Soon we must find more effective ways of assessing the reliability of both electronic and non-electronic parts.

There must be a major effort by industry if these goals are to be attained. This will involve industry-government cooperation, the awareness by industry of all the government reliability programs, the search for new methods of conducting reliability efforts, the creation of new administrative and contractual procedures, and the accelerated development of the testing phases of reliability.

REVIEW: As expected this is an exhortation for those in the field to bear down hard on the problems facing them. It covers the main points in the DoD reliability problems, but suggests nothing new. The suggestion that "Our deficiency in reliability progress today, then, is not primarily one of motivation" is misleading and illustrates a major, unmentioned deficiency in our reliability programs. Right now, if everyone from puchasing agents through designers and production workers to company presidents and government project monitors were pushing reliability as hard as they now know how, many of our reliability problems would melt away. One of our largest problems is how to change the procurement system so that industry can afford to sell systems which are as reliable as engineers know how to build. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1652 -1
Code 814

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Guaranteed reliability at a minimum cost

AUTHORS: M. C. Haddon, Lockheed Aircraft Corporation, Burbank, California
H. Chesebrough, Chrysler Corporation, Detroit, Michigan
R. E. Kirby, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania

SOURCE: IEEE Transactions on Reliability, vol. R-13, March, 1964, pp. 8-13 (presented in an industrial panel discussion at the Tenth National Symposium on Reliability and Quality Control, Washington, D. C., January, 1964)

PURPOSE: To discuss qualitatively the guaranteeing of reliability, and the benefits of so doing.

ABSTRACT: The three speakers are each represented by a separate discussion.

<u>M. C. Haddon</u>
Three assertions can be made: Guaranteed reliability is coming, it is a good thing, and it can be reasonably implemented. Incentive fee contracts can be valuable in providing the prime and subcontractors with an economic incentive to provide high reliability. It is essential that the contract carefully detail the exact way the reliability is to be measured. Not much experience is available on which to base the success of this type of contract in improving reliability, but it is expected to work out well.

<u>H. Chesebrough</u>
The automotive industry, through pressures of the market place, is providing higher reliability at no extra cost to the customer or to the manufacturer. This is due to the steady increase in quality of cars which the manufacturers have been able to attain. Extended warranties, the visible evidence of improved reliability, can not only be a good sales influence but they can help provide workers with pride and an incentive to build quality into the product. Much field failure information is collected and computers are required for assistance in effective analysis.

<u>R. E. Kirby</u>
Total cost of a part, first cost plus repair and replacement, is the important cost. Not all customers realize this yet, but educational efforts are being made. The aim in reducing post-purchase costs is to do the hard work and take the risks in the factory where proper controls exist. The product that is sold can then be much more reliable than otherwise. Molecular electronics are an example of this technique.

REVIEW: A most important statement made by the last two authors is that the high reliability programs in industry can pay for themselves; they are practical. The discussion of incentive contracts was cautious and somewhat incomplete. No mention was made of the

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

problem of multiple incentives such as delivery, cost and reliability, and the problems to which they give rise.

There is some vagueness about what guaranteed reliability actually is. In one chart, reliability is used as a synonym for MTBF. There seemed to be some ambiguity in the discussion of the present automobile guarantees as compared to guaranteed reliability. One might suggest that in the cases of a single item (such as one car per customer) the term guaranteed reliability has no realistic meaning (where reliability = probability of success...).

Quantitative reliability requirements, for very high reliability, are very difficult to demonstrate (the same is true for very high quality). It may well be that the time has come not to guarantee an MTBF or some such thing, but to guarantee the product. This is what the automotive industry does for consumers; perhaps the defense industries can move in the direction of doing the same for the government. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1653
Codes 838;872;882

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure time for a redundant repairable system of two dissimilar elements

AUTHOR: D. P. Gaver, Jr., Carnegie Institute of Technology and Westinghouse Research Laboratories, Pittsburgh, Pennsylvania

SOURCE: IEEE Transactions on Reliability, vol. R-13, March, 1964, pp. 14-22

PURPOSE: To analyze the failure time of a redundant repairable system of two dissimilar elements.

ABSTRACT: The distribution of time to failure for a system consisting of two dissimilar elements operating redundantly and susceptible to repair is discussed. It is assumed that the times to failure for the two system elements are independent random variables from possibly different exponential distributions, and that the repair times peculiar to each element are independently distributed in an arbitrary fashion. For this basic model a derivation is given of the Laplace transform of the distribution function of time to system failure. An explicit formula is given for the mean time to system failure, a natural approximation to the latter is exhibited, and numerical comparisons indicate the quality of this approximation for various repair time distributions.

In a second model the possibility of system failures due to overloading the remaining element after a single element failure is explicitly recognized. The assumptions made for the basic model are augmented by a stochastic process describing the random occurrence of overloads. Numerical examples are given. The above models may be easily modified to account for delays in initiating repairs resulting from only occasional system surveillance. They may also be used to account for random severe environments which cause system failures regardless of redundancy. (Author in part)

REVIEW: This is a mathematical paper. The results can be of use to design engineers, but, in some cases, a knowledge of Laplace transforms will be required in order to apply them. (While not all the equations were checked--the derivation is rather sketchy--the work appears to be of high quality. Anyone using these results will want to go over the derivations in any event to be sure that all of the implications are understood.)

This is an extension of the work presented in the paper by the same author covered by Abstract and Review Serial Number 1112.
##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1654
Codes 821;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The reliability of redundant multiple-line networks

AUTHOR: P. A. Jensen, Electronics Division, Westinghouse Electric Corporation, Baltimore, Maryland

SOURCE: IEEE Transactions on Reliability, vol. R-13, March, 1964, pp. 23-33

PURPOSE: To develop a procedure for determining a lower bound on the reliability of multiple-line networks.

ABSTRACT: A multiple-line network is one in which a single circuit is replaced by several identical circuits operating in "parallel". There generally are restorers in the network which take the outputs of the several identical circuits, derive the correct output and then pass it on. Triple majority voting logic is an example. A symbolic representation of the network is introduced. The lower bound on reliability is calculated using the method of Proschan and Esary. It uses the concepts of a "coherent system", a "cut", and a "minimal cut" to describe the system and its failures. This paper introduces a method of matrices for finding the minimal cuts. The method is quite general, although the assistance of a computer is required in complicated situations.

REVIEW: The paper appears to be sound, although not all of the development was checked. It is important to recognize that the model for the system admits of only success or failure. If the actual system is not properly assessable in this way, the analysis may not apply. For example, in majority-vote logic, the simple term "failure" is not an adequate description since an output may fail to either ZERO or ONE. The failure behavior of the system now depends on which way the element fails (see Abstract and Review Serial Number 1268). A similar situation might arise where failures are described as either OPEN or SHORT.

Two minor criticisms, which do not affect the validity of the results, are

1. The characteristics for a minimal cut are stated as "sufficient". If they are not "necessary", the cut may be more than minimal. This does not invalidate the result, but the reliability bound may be lower than it need be.
2. The input source matrix is apparently improperly defined. It should state that it shows output functions in addition to the restored functions. (In addition, the matrix examples include the row number inside the matrix--apparently an editorial error.)

All in all the paper is a good one, if studied carefully in the light of the above comments. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1655
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Empirical parameter variation analysis for electronic circuits

AUTHOR: Stuart Klapp, SCM Corporation, Data Processing Systems, Oakland California

SOURCE: IEEE Transactions on Reliability, vol. R-13, March, 1964, pp. 34-40

This paper appears to be identical to the one covered by Abstract and Review Serial Number 1170. However, no reference to the previous publication is given. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1656
Codes 863;872

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The effectiveness of "on-board" maintenance

AUTHOR: Royal P. Fisher, HRB-Singer, Inc., State College, Pennsylvania

SOURCE: IEEE Transactions on Reliability, vol. R-13, March, 1964, pp. 41-47

PURPOSE: To derive expressions for estimating the allocation of spares to be carried for maintenance during a mission.

ABSTRACT: Since the probability of failure during a mission is never zero, it is interesting to see what reliability improvements are possible by considering repair of failure during the mission (called "on-board" maintenance). It is assumed that the repair is effected in a very short time. When there are limits on volume and weight, what spares should be carried and what should not? The equation for reliability of a system with primary and other modes of operation is given. The increase in reliability for a given spare can be calculated, and the volume and weight are known. While linear programming might be used to solve the problem, it is just as easy to use Dantzig's solution of the knapsack problem. Each spare is assigned three numbers: a criticality, volume and weight. The spares are listed, in two lists, in descending order of criticality/volume and criticality/weight. Cumulative curves for each list can be plotted giving increase in reliability vs. total weight or volume. It is likely that the two lists will give similar solutions. A brief example is given.

REVIEW: The paper deals with an important topic and, within the limits of the model, chosen for the analysis, could be helpful to those having this problem. There are some difficulties, however. For example:

1. The introductory discussion suffers from being too closely tied to the "exponential" distribution, but this does not affect the results.
2. There is a minor confusion in notation ($R'C_i$ and R_i) but it is not serious.
3. The concept of criticality is nowhere related to reliability, but presumably it would be the increase in system reliability due to carrying the spare.
4. The example is a little awkward since it implies that the increases in system reliability are independent of initial reliability.
5. The derivation seems to ignore the fact that increases in system reliability depend on the present system reliability. Thus the increase due to spare B depends on whether or not spare A is carried; the paper implies that the increases are independent.

##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1657
Codes 551;851

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Selecting most reliable electronic components

AUTHOR: Irwin Nathan, Aerospace Systems Division, General Precision, Inc., Little Falls, New Jersey

SOURCE: 1964 IEEE International Convention Record, Part 9, New York, New York, pp. 1-8, March, 1964

PURPOSE: To present a non-parametric analysis of life test data using ranking methods.

ABSTRACT: Life tests will generally be accelerated, for many reasons, and the step-stress life test has many merits as an accelerated test. Naturally the engineers involved will need to assure themselves that the test conditions and failure definitions are not unrealistic.

The test proposed is based on the Mann-Whitney U statistic. Assume that only two groups are being compared. The results of the life tests are combined (but retaining the group identity) and ranked. The U statistic is calculated from the rank numbers of each item. The one-sided tests are more powerful than the two-sided tests. If the number of failed items is large enough, a Gaussian approximation can be used. Two examples are given, and also a table of critical values of U. The U statistic has almost as much discriminating power as a parametric test even when the distribution is known. Thus its use is recommended under these circumstances because of its simplicity and adequacy.

REVIEW: The article is basically in two parts. The first is a discussion of step-stress life tests. There is some confusion here since the description does not seem to correspond to a widely used step-stress test wherein the stress is increased in steps until failure occurs. (See, for example, Abstract and Review Serial Number 165.) This does not affect the second part of the paper however, since the analysis is applicable to any kind of ordered data (assuming that ties do not exist).

The analysis of the ranked data presented here is a valid one and should be useful. It can well free engineers from an undue dependence both on complicated models which are usually inadequate and on statisticians who must interpret them. It might be pointed out, however, that in the case of only two groups, one may merely wish to pick the group most likely to be better; i.e., the acceptance or rejection of this null hypothesis may not be the desired decision. Then the group with the best ranking would be chosen regardless of the confidence level involved in rejecting the null hypothesis of any difference between the two. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1658
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Failure predestination

AUTHORS: R. Hilow and J. Klion, Rome Air Development Center, Griffiss AFB, New York

SOURCE: 1964 IEEE International Convention Record, Part 9, New York, New York, pp. 9-17, March, 1964

PURPOSE: To outline an overall concept of component life which is based on the premise of thresholds of failure.

ABSTRACT: Parts generally react to their environment by degrading during the course of time. For a particular failure mechanism, the amount of damage (degradation) necessary to cause failure of an individual device is called the threshold. If the magnitude of a threshold can be estimated by a non-destructive test, then those parts with lower thresholds can be eliminated from the population and the failure rate during the earlier period of use is decreased. The amount of decrease depends on the knowledge of the thresholds and their non-destructive estimators. Naturally, costs are involved. Most non-destructive tests do not narrowly estimate a particular threshold so that some good parts may also be discarded.

REVIEW: This paper seems to consist of a short incomplete discussion of a cumulative damage theory of failure and an outline of screening-type tests. The two are related in that those parts with a low threshold for a particular failure mode are to be eliminated by the tests. Neither concept is new in itself, but the particular organization here is certainly reasonable. The model is not universally applicable, especially in its present form; it does obviously have many present uses. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1659
Codes 775;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability screening using infrared radiation

AUTHOR: Anthony J. Feduccia, Rome Air Development Center, Griffiss AFB, New York

SOURCE: 1964 IEEE International Convention Record, Part 9, New York, New York, pp. 18-23, March, 1964

PURPOSE: To describe a method for observing abnormal heating of devices.

ABSTRACT: When an electronic circuit is normally powered, all of the parts will emit radiation. The measurable part is well in the infrared and can be measured by conventional techniques. An infrared picture can be obtained or an average for an element or part of an element can be read. Those parts which emit abnormal amounts (too much or too little) of radiation may also have a shorter life. In connection with a physics of failure program, the correlation between life and emitted radiation can be established (in some cases only the too high or too low may correspond to shorter life). Thus a screening technique is available for eliminating potential early failures.

REVIEW: This appears to be an excellent technique for eliminating faulty units. Other papers on this subject have been covered by Abstracts and Reviews Serial Numbers 626 and 993. Just how widespread its use is in production is not known, but appears to be slight judging from the small number of papers dealing with it. It deserves more attention than it seems to be getting. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1660
Codes 844;864

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability predictions of electromechanical functions--estimate or guesstimate

AUTHORS: Donald W. Fulton, Rome Air Development Center, Griffiss AFB, New York and George Chernowitz, American Power Jet Company, Ridgefield, New Jersey

SOURCE: 1964 IEEE International Convention Record, Part 9, New York, New York, pp. 24-30, March, 1964

PURPOSE: To discuss the impact of electromechanical and mechanical failures on electronic systems, and the deficiencies in present nonelectronic reliability prediction methodology.

ABSTRACT: While electronic failures usually account for many more system malfunctions than do mechanical ones, the mechanical failures tend to cost much more. The predictability of mechanical failures is poor. They tend to not have a constant hazard rate and data on field failures are scarce. The use of generic failure rates is shown to be inadequate. Major improvements in reporting field failures would help; some suggestions are made.

REVIEW: Most of the material here is not new with the exception of the calculation of the repair cost of mechanical vs. electronic failures. The complaints about the lack of reliability numbers for mechanical components have been voiced before, and many suggestions have been made for improvement. The very brief review of RADC activities in this area is of interest. The problem of adequate reporting of field failures is likely to be with us for a long time. Attempts to alleviate the situation are worthwhile, but probably are rarely very effective. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1661
Codes 720;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A new system providing reproducibility and high reliability in soldered and insulated wire terminations

AUTHOR: Paul Sherlock, Raychem Corporation, Redwood City, California

SOURCE: 1964 IEEE International Convention Record, Part 9, New York, New York, pp. 99-104, March, 1964

PURPOSE: To describe a new system for making soldered connections.

ABSTRACT: The concept of an insulated soldered termination accomplished in a single, controlled operation has recently been implemented through the development of a device which consists of a fluxed solder preform inside a heat-shrinkable, encapsulating, insulating sleeve. In a controlled-heating operation the sleeve shrinks, sealing rings in the ends melt, and solder flows to form an encapsulated termination which can be reproduced with a consistent reliability impossible with more conventional soldering techniques. (Author in part)

REVIEW: No life data as such are given, nor are any quality data such as the fraction of defective joints to be expected. In the absence of this quantitative information, about all that can be said is that the method looks quite interesting and should be looked into carefully. There is no way of getting rid of the flux (which has been a problem in some cases), although the paper claims that no trouble results from this.

In a private communication, the author says that these solder sleeves have been in use for two years in large quantities on a number of vital military and space projects. He also emphasizes that extensive tests have shown absolutely no ill effects from the flux residues. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1662
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electronic transient suppressors

AUTHOR: V. W. Vodicka, Joslyn Electronic Systems Division, Goleta, California (present affiliation: Applied Magnetics Corporation, 749 South Kellogg Avenue, Goleta, California 93017)

SOURCE: 1964 IEEE International Convention Record, Part 9, New York, New York, pp. 172-177, March, 1964

PURPOSE: To review the methods of suppressing electrical transients in electronic equipment.

ABSTRACT: Electrical and electronic equipment are often damaged by transients. These natural or manmade phenomena can be suppressed or eliminated by the use of modern Electronic Surge Arrestors.

The basic component is a gas-filled spark gap, using isotope prompting, capable of operating in less than a microsecond at various preset "clamping" levels (150V - 30 KV). These are combined with other specially developed components such as silicon carbide resistors, multilayer diodes, SCR's, etc., to further reduce the transient levels and to produce redundancy where needed.

The following equipment can be protected: voice, data, carrier communication equipment on wire and cable, VLF to UHF receivers, transmitters, antennas, computers, power supplies, generators, motors, etc. (Author)

REVIEW: This is a good treatment of the methods of suppressing transients and covers a wide variety of cases. It seems to deal more with externally-induced transients than with internal ones (such as the dip caused by a high current load momentarily put across a power supply). ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1663 -1
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Design Guide: Electrical terminations (in five parts)

SUBTITLES AND AUTHORS:
1. Understanding failure, S. Deas Sinkler, Assistant Editor (Machine Design)
2. Soldered connections, Howard H. Manko, Alpha Metals, Inc., Jersey City, New Jersey
3. Crimped connections, Franklin Wells, AMP Inc., Harrisburg, Pennsylvania
4. Wrapped-wire connections, James E. Schaeffer, Vitro Laboratories, Silver Spring, Maryland
5. Welded connections, Weldon V. Lane, U. S. Army Electronics Research & Development Laboratories, Fort Monmouth, New Jersey

SOURCE: Machine Design, vol. 36, May 21, 1964, pp. 183-214 (1: pp. 184-189, 2: pp. 190-195, 3: pp. 196-201, 4: pp. 202-208, 5: pp. 209-214)

PURPOSE: To give detailed information on the major types of electrical connections.

ABSTRACT:

1. In addition to cost, the major factors to be considered in the selection of a method of connecting electrical conductors include: joint life, connection density, compatibility, environment, preparation, mass producibility, process control, inspectability, repair time, repair skill, maintenance tools, and repairability. In a particular application, some of these are more important than others. However, each must be considered as a potential source of connection failure. The following are discussed in some detail: joint life, high-density packaging, incompatibility, mechanical weakness, whiskers, temperature extremes, and low-pressure difficulties. Fourteen references are cited.

2. The advantages of the use of soldering as a bonding technique are cited. These include the following: relatively easy to make, truly repairable connection, visually inspectable integrity, adaptability to high-speed automation, and economical method, requiring no additional hardware. Soldered joint properties are described. Other topics discussed include: selecting materials, designing soldered joints, and production considerations. One major reference is cited.

3. Crimped connections provide a uniform quality, gastight, metal-to-metal bond for stranded or solid wire without requiring application of heat or use of an intermediary material. They are particularly suited to applications requiring: insulation support, preinsulation, high-speed application from reels of terminals,

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

coaxial-cable connections, postinsulation, insulation piercing, choice of stranded or solid wire, and wide variety of wire and terminal materials. Crimped-joint characteristics are described. Other topics discussed include: specifying terminals and wire and applying crimped connections. Five references are cited. (Author in part)

4. Although wire wrapping was developed for the specialized connection needs of vast numbers of relays and patching circuits, this termination system has evolved into a major connection type suitable for many medium and low-density applications. The performance of the wrapped joint is described. Other topics discussed include: specifying terminals and wire and applying wire wrapping. Five references are cited. (Author in part)

5. Although welding is an old art, its application to electronic packaging is new. In applications in which repairability of joints is a negligible factor, its advantages include the following: minimum heat transfer to adjacent components in joining heat-sensitive devices, minimum joint volume--welds do not add to the dimensions of conductors being joined and package density can be high, elimination of flux in the joining process avoids contamination of critical parts, high component operating temperatures, mechanical strength comparable to that of parent materials, minimum joint weight, and high reliability under extreme mechanical and thermal stresses. Topics discussed are: resistance spot welding, pulsed-arc and percussive welding, thermocompression bonding, ultrasonic welding, series welding, laser welding, electron-beam welding, welded-joint characteristics, and welded-joint applications. Eight references are cited.

REVIEW: This collection of papers offers a fine example of technical writing, conveying a maximum amount of information in return for a minimum amount of effort on the part of the reader. The papers have essentially parallel structures, which is a very helpful feature in treating a topic of this kind. The advantages and other features of each of the methods of connection are competently and cogently presented. Collectively these papers constitute a handy and useful guide for anyone concerned with the selection of a method of electrical connection. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1664 -1
Codes 715;782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Designing for the military: Radiation-resistant equipment -- Design data and guidelines (An Electronic Design Special Report)

AUTHOR: Alan Corneretto, News Editor

SOURCE: Electronic Design, vol. 12, June 8, 1964, pp. 35-46, 48-55

PURPOSE: To identify potential military radiation environments and provide guidelines in component selection, circuit design, and test and qualification of radiation-resistant equipment.

ABSTRACT: The report covers three major areas of interest designated by the subtitles indicated below.

The radiation environment and component selection
Prompt radiation, generally gamma rays, is emitted from nuclear explosions as an intense, microsecond burst. A 1-Megaton high-altitude explosion can produce a 1-μsec gamma dose rate of 10^7 roentgens/sec many miles away. In such an environment, electronic equipment may absorb as much as 10^6 to 10^{12} rads of prompt radiation. Neutron flux causes most of the permanent damage to electronic components and materials. Gamma pulse and flux generally cause transient effects. Metal film and wirewound resistors, glass, mica, and ceramic capacitors, insulating materials, transformers, solenoids, and relays can be built to withstand 10^{16} neutrons/cm^2. A fast neutron flux of 10^{14} n/cm^2 permanently reduces the forward current gain of quality 400-Mc silicon transistors to 0.5-0.7 of their initial gain. Bulk integrated circuits are more resistant to radiation than conventional circuits. Developmental low-frequency, thin-film integrated circuits appear to be an order-of-magnitude better than bulk monolithic circuits. Charts are included showing radiation doses for threshold and completely degrading damage effects to various active and passive devices, elastomers, and plastics.

Designing hardened equipment: several methods are useful
Producers of hardened military equipment use one or more digital and analog methods to analyze their circuits for radiation resistance. The general design goal in hardening circuits and equipment is to minimize or optimize charge redistribution. The most common redistribution situation in linear circuits is for a circuit to be saturated by transients and to behave like a switching circuit, having on, off, and recovery times controlled by active and passive devices and their charge distribution. Transistors should be selected for their relative insensitivity to radiation. Silicon is still generally preferred to germanium. Alloy construction is more desirable than grown or diffused techniques,

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

and narrow bases are preferable to wide ones. Low bias levels, especially of first stages, and, in general, low impedance circuits are more resistant to radiation effects. Entire circuits should be potted in compounds that will not conduct when irradiated. Several examples of hardened circuits are shown.

Test and qualification: difficult at best
Equipment built under military contract and designed for a specified performance in particular radiation environments must be tested to verify that design goals have been met and to qualify the equipment for acceptance. Contracts generally specify test, rather than actual environments, for obvious reasons. Further, the test environments specified are almost always those produced by specific reactors, accelerators, and other nuclear radiation sources. Pulsed thermal reactors typically produce peak gamma exposure rates of 3×10^7 roentgens/sec and neutron flux rates of 10^{16} n/cm^2/sec. Their pulses are about 10 milliseconds long. Pulsed fast reactors produce comparable peak rates with shorter pulses on the order of 50 μsec wide. Flash X-ray units and electron beam accelerators are also available sources. Test facilities are used in two ways: as go--no-go test or to verify the design analysis of the equipment. An additional difficulty in testing for nuclear effects is the inevitable influence of the test equipment used, particularly the cables that carry power into and signals out of the chamber enclosing the radiation source. Composite air-and-dielectric cables have been found to be more sensitive to radiation than solid dielectric types.

REVIEW: This report summarizes the content of a number of recent papers on pulsed radiation effects in a generally consistent fashion, giving a good over-all view of the problems. The various radiation units are described rather than quantitatively defined. Probably wisely, no attempt is made to interrelate the effects of the various types of radiation. The dose rates and integrated doses for the 1-Megaton blast are for two different locations. The equipment environment is in the relatively near vicinity of the blast. The methods by which ionizing damage is incurred are not very accurately described.

The first portion of the report with its specific data, tables, and evaluations is of the greatest interest. The section on radiation hardening techniques is more qualitative and not always as lucid as it might have been. The subtitle on the third part is most apt. Only the bare bones of the problem are, or probably can be, treated there. Nevertheless, a greater insight into the range of problems (transient, permanent, air ionization, chemical reactions, and induced radioactivity to suggest a few) should have been included. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1665 -1
Code 720

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable hand soldering techniques

AUTHOR: Howard B. G. Kittredge, George C. Marshall Space Flight Center, NASA

SOURCE: 5 pp., presented at the SAE Automobile Week, Detroit, Michigan, March 30 - April 3, 1964, Society of Automotive Engineers paper 830A

PURPOSE: To review the techniques used in obtaining reliable hand soldered connections as specified by the George C. Marshall Space Flight Center.

ABSTRACT: This paper presents those practices of hand soldering that must be carefully controlled in order to obtain a reliable soldered connection. Early methods of joining electrical conductors with solder consisted principally of preparing a sound mechanical connection and then applying sufficient amounts of flux, solder, and heat to accomplish what was believed to be an electrically sound termination. Termination made in this manner, and not soldered, would escape detection during prelaunch functional tests, but would fail when exposed to the extreme vibrations and "g" loads imposed during vehicle flight.

Reliable soldered connections are comprised of the following ingredients:
Material Selection: A properly applied hot dip, tin-lead coating is the most desirable surfacing to be used on printed circuit boards. Electrodeposited tin lead or immersion tinning is to be avoided, as is immersion gold plating.
Controlled Cleanliness: All dirt, grease, scale, and oxides must be removed from the surface to be soldered. A "pinch type" soft copper braid cleaning tool is useful in cleaning leads but should not be used on gold plated leads. Gold plated boards require the removal of gold from the area to be soldered.
Lead Wrap: Leads should be formed on an identical terminal as an armature and cut to a minimum length. Lead bend will generally be 90-270 degrees. Minimum lead wrap practically eliminates the chance of an unsoldered connection escaping detection and allows better inspection of the connection.
Heat Management: We must be able to raise rapidly the temperature of the component parts of a joint to a degree sufficient to melt the solder while preventing damage to insulation and heat-sensitive components. Cartridge type 40-50 watt elements with unplated copper chisel tips are recommended.
Solder: The total amount of solder applied should be only as much as is required to form a concave fillet between the terminal and the lead.
Flux Removal: All flux residue should be completely removed using

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

alcohol or other non-corrosive solvents.
When these requisites have been fulfilled, the result will be a soldered connection possessing a high degree of inspectability.

REVIEW: This is a readable, well-illustrated paper with specific recommendations in a critical area. The use of only partial wrap in making connections and the use of unplated soldering tips may upset some production personnel. The paper makes no attempt to discuss in any way other types of connections.

A paper discussing the NASA hand soldering program with emphasis on the associated specifications was covered by Abstract and Review Serial Number 1494. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: When is a life test truly accelerated?

AUTHOR: Ralph E. Thomas, Battelle Memorial Institute, Columbus, Ohio

SOURCE: Electronic Design, vol. 12, January 6, 1964, pp. 64-66, 68, 70, 71

PURPOSE: To set forth the principles, limitations, and method of use of the Arrhenius equation and to introduce the more general Eyring model of acceleration of life testing.

ABSTRACT: As failure rates become as low as 10^{-6} per thousand hours, the only economically feasible way to life test components is by an acceleration technique. In these tests the parts are operated at higher "stress" levels than required for normal operation. The term "stress" is intended to include operating temperature, junction temperature, power dissipation, etc.

One complication in analyzing the accelerated test data is that, as the stress level is increased, the mode of failure may change; that is, the part may fail for a different cause at a higher stress. When several degradation processes occur simultaneously, the dominant degradation process may change if the temperature is increased. Further interaction problems arise when several stresses are increased at the same time.

Research indicates that activation energies and basic material properties may be the proper parameters for describing the aging of electronic parts. These parameters occur in the rate process equations of Arrhenius, and the more general equations of Eyring. The Arrhenius model is simple and applies when aging is produced solely by thermal stresses, and is of the form $R(T) = \exp(A-B/T)$, where A and B are empirical constants independent of temperature T. The more sophisticated Eyring model may be used when aging is produced by both thermal and nonthermal stresses. It is of the form $R_o = AT \exp(-B/kT)$, where k is Boltzmann's constant and A and B are empirically determined. In the presence of a nonthermal stress, S, such as voltage, this rate of degradation is multiplied by two factors, f_1 and f_2, to give $R = R_o f_1 f_2$, where f_1 and f_2 are again exponential functions each with an additional constant which can be determined. The constants A, B, C, and D so determined will completely characterize each aging mechanism.

A step-by-step procedure is outlined for analyzing accelerated test data using the Arrhenius model, from which acceleration factors and activation energies can be obtained. The latter can

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS
AND TECHNICAL REVIEWS

be used to identify the underlying aging mechanisms. (Author in part)

REVIEW: This is a relatively short paper with the ring of authority in the exposition of the application of the Arrhenius and Eyring models to accelerated life testing. Although a particular example involving the aging of powered and unpowered transistors under temperature stress is included, this is a basic paper rather than one outlining applications to a wide variety of test stresses. The point is quite clearly made that the Arrhenius equation is based only on temperature stress with the implicit warning that it may not be applicable to other stresses. On the other hand, a fairly firm position is taken that the Eyring model not only fits the aging process, but fundamentally describes it.

This paper is essentially a summary and adaptation of the paper covered by Abstract and Review Serial Number 1407, which is cited as Reference 3 in the present work. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1667 -1
Code 775

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Nondestructive system for the inspection of solder joints

AUTHOR: Willard L. Zinke, Eastman Kodak Company, Apparatus & Optical Division, Rochester, New York

SOURCE: Materials Evaluation (formerly Nondestructive Testing), vol. 22, pp. 219-224, May, 1964

PURPOSE: To describe a new nondestructive method for the inspection of solder joints.

ABSTRACT: Because of the ever-increasing complexity of military and civilian electronic apparatus and the more and more stringent reliability requirements specified for the end products--electrical circuit reliability has become increasingly important. Electrical component reliability has been improved until a condition has been reached wherein circuit reliability is often limited only by the soundness of soldered joints between components. Industry and government agencies have continuously worked to develop a means of improving soldered joint quality. For the most part, emphasis has been placed on exercising better control over the soldering process and maintaining high standards for visually judging the quality of finished joints.

In 1960, Frankford Arsenal recognized the need for a method to more adequately determine the quality of a completed soldered electrical joint in a nondestructive manner and as a separate step in the manufacturing process. The inspection system described in this paper is basically a refinement of the commonly used visual inspection for surface defects. By making these defects luminous under ultraviolet light, the visual inspection becomes more reliable, less time consuming, and less dependent on operator skill and judgment. The system is useful for the inspection of soldered joints in any electronic assembly, but it is particularly applicable to printed circuit construction. It is nondestructive, compatible with any manufacturing rate, and sensitive enough to detect quality trends before obviously defective material is produced. The apparatus required is inexpensive and can be assembled from ordinary commercial items.

Continuous tests were performed throughout the study to discover if the inspection system chemicals might degrade component reliability. The principal areas investigated were d-c electrical leakage that might result from chemical contamination of components and corrosion or similar aging effects that might occur as a result of chemical contamination. No degradation of ordinary materials commonly used in electronic assemblies was found to occur as a result of exposure to the system chemicals for long periods of time and at various levels of temperature and humidity. (Author)

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: This is a detailed, informative paper in which the author gives step-by-step instructions on the use of a fluorescent penetrant oil to reveal surface defects under ultraviolet light. (This nondestructive method of testing is widely used in the metals fabrication industry.)

Although the process has no deleterious effects on electronic components it would be interesting to know how it would affect relay contacts if used to check soldered joints on relay wiring.

The author, in a private communication, has pointed out that good cleaning after inspection should restore all relay contacts to their virgin state. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1668 -1
Code 830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Two self-healing circuits: one grows whiskers, second solders breaks

AUTHOR: (Editorial Matter)

SOURCE: Machine Design, vol. 36, January 2, 1964, p. 12

PURPOSE: To present a news item describing self-healing electrical conductors.

COMPLETE ITEM: Electronic circuits can now be designed to automatically repair themselves after failure under stress. Two types of self-healing circuits have been developed and successfully tested by Honeywell's Aeronautical Division. The first involves spontaneous growth by the conductor of metallic whiskers--the whiskers growing across the circuit break. The second uses a special remeltable alloy coating over electronic conductors to seal the break.

The whisker growth is best obtained from an alloying of hard metals with soft ones, creating hard-matrix soft-fill alloys, according to Honeywell. The technique could be applied to ground, airborne, or space electronic systems with only moderate changes in current technology.

Greatest whisker density and fastest growth rate were observed in an alloy of tin, aluminum, and magnesium. Tin whiskers were "extruded" from the hard aluminum-magnesium matrix, particularly at compressed or stressed regions.

There are many advantages claimed for the whisker-growth technique: No external energy is required, and spontaneous generation of whiskers occurs only where needed--it can be inhibited where not wanted. Additionally, repairs can be repeated, and whisker generation can occur several times as repaired regions are reopened. Time required to bridge a circuit break is given as the main disadvantage. Several days are necessary for the spontaneous repair of breaks.

Remeltable alloys coated over electronic conductors exhibit what is described as "ohmic resoldering"--melting of the alloy by resistance heat from a nearly failing connection, which causes the alloy to flow into the break and maintain conductivity. An indium-gallium alloy was most successful, exhibiting great mechanical flexibility as well as resoldering capability. The alloy remains semisolid throughout typical military temperature ranges (-75 to 250F) and adheres well to standard solder and to copper laminates. Further, it does not wet the surface of circuit

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

boards, and withstands both vibration shocks from 10 to 200 g and 1/4 in. displacements at 10 cps through 2500 cps when coated over standard solder.

Honeywell engineers are now conducting advanced studies of the whisker growth and remeltable alloy techniques and are researching semiconductor self-repair approaches for the Air Force.

REVIEW: This article reports on a very interesting design idea. However, it would have been more valuable to readers interested in the details if the reporter had given at least one reference to a relevant paper in the technical literature. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1669 -1
Codes 720;830

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Electromechanical relays
Part 1: Design and production of reliable electromechanical relays

AUTHOR: Norman Hyde, Hellerman Deutsch, Ltd. (East Grinstead, Sussex, England)

SOURCE: Electronic Components (incorporating Radio and Electronic Components), vol. 5, pp. 391-396, May, 1964

PURPOSE: To discuss the design and production of a reliable relay.

ABSTRACT: Advantages inherent in relays are: (1) a single transistor cannot replace a relay; several other components of varying reliability are also needed, (2) the electrical isolation of input and output, (3) tolerance of high overload voltage, and (4) tolerance of high temperature.

Present-day requirements for relays might be listed as follows:

1. Size--Maximum volume 0.3 cubic inch, 0.15 preferable.
2. No. of Contacts--2 changeover, 4 changeover preferable.
3. Switching Capacity--(a) Low-level circuits; (b) 2-3A resistive load 30V d.c.
4. Ambient Temp.--Performance throughout temperature range -60°C to +150°C.
5. Shock--100G at 11ms.
6. Vibration--50G at 10-1000c/s.
7. Acceleration--100G.
8. Reliability--Failure rate better than 0.01% per 10,000 operations.

To meet such requirements relays must have:

(a) Robust construction.
(b) Balanced armatures with low friction and close dimensional tolerances.
(c) Rigid coil construction.
(d) Efficient magnetic circuit.
(e) Welded springs.
(f) No organic materials in contact area, i.e. separate contact area.
9. Welded final enclosure.

A detailed description is given of the design and manufacture of a special high-reliability double-sealed dry reed relay.

REVIEW: This is an excellent description of the efforts made by a particular manufacturer to produce a reliable relay. The major topic of interest is the discussion of the various steps taken to reduce the probability of contamination of the relay contacts. In

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

a private communication the author has pointed out that to check whether or not contamination has been obliterated it is necessary to measure contact resistance at 10 mV open circuit voltage to an acceptance figure of a few milliohms. The appendix to this article shows a machine which has been developed to do this. The author also mentioned that the American "miss" test has an acceptance value of 500 ohms, which is not acceptable in the U. K.

Other papers concerned with the manufacture of reliable relays have been covered by Abstracts and Reviews Serial Numbers 1556 and 1565. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: A comparison of permanent electrical connections

AUTHOR: G. W. Mills, Bell Telephone Laboratories, Columbus, Ohio

SOURCE: The Bell System Technical Journal, vol. 43, pp. 1067-1102, May, 1964 and Bell Laboratories Record, vol. 41, pp. 366-369, October, 1963

PURPOSE: To describe the results of tests of the reliability of four types of permanent wire connections to terminals.

ABSTRACT: Over a billion electrical connections are made each year in Bell System equipment. These connections are so important that the operation of all switching systems now used and to be used in the future are dependent on their reliability. Most permanent connections are made during the manufacture and installation of central office equipment. The four main types now being used are: solderless wrapped, soldered, percussive welded, and resistance welded.

This paper describes a study which compares the above four types of permanent electrical connections under environmental conditions of vibration, shock, temperature extremes, corrosion, humidity, and bending. Only good-quality connections were included in this study, and they represented the current state-of-the-art for each type. Under these conditions the connections showed no significant degradation in their electrical characteristics as long as they remained mechanically secure. Differences in the four types of connections were therefore assessed in relation to their mechanical characteristics. Consequently, one of the more important results of the study was the recognition of fatigue life as the most important mechanical connection characteristic when comparing connections which meet the high standards of the Bell System for electrical stability. Using fatigue life as a basis for comparison and soldered connections as a reference standard, the major conclusions with regard to general wiring (the connection of wires to terminals, such as surface and local cable wiring) are as follows for the conditions that existed in this study:

(a) monitored percussive welded connections are superior to soldered connections;

(b) over-all, solderless wrapped connections are essentially equivalent to soldered connections;

(c) resistance welded connections are significantly inferior to soldered connections.

Although differences were found among the types of connections, no evidence was obtained that any of the connection types are not satisfactory as presently used in normal Bell System applications. (Author in part)

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

REVIEW: The first-named of these two papers (see SOURCE) is a comprehensive and detailed report of the subject study. As such, it should be of considerable value to designers concerned with the selection of an electrical connection to be used in a given environment. Test procedures and results are fully described, and conclusions are clearly presented.

The second paper is a brief, essentially qualitative description of the same topic. It will be of interest to the reader who does not wish to go into the details, but who wants a general knowledge of the conclusions.

Another recent paper on the comparison of electrical connections was covered by Abstract and Review Serial Number 1525. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1671
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The design engineer applies reliability techniques

AUTHOR: Donald G. Shuda, Sylvania Electronic Systems, Sylvania Electric Products Inc., Williamsville, New York

SOURCE: solid/state/design, vol. 5, May, 1964, pp. 29-32

PURPOSE: To describe the use of redundancy in improving the reliability of a satellite-borne amplifier.

ABSTRACT: A case history of a design effort in which reliability techniques were applied at the start by a design engineer may prove of value to other design engineers faced with a similar requirement. As part of a program to design a solid state transmitter for use in a satellite, the author was given the responsibility for designing a VHF amplifier having a high degree of reliability.

A preliminary circuit layout of the VHF amplifier was examined to evaluate its reliability. The circuit could be designed in either of two ways: as a single, non-redundant configuration, or as a redundant circuit. Two approaches could be used in the redundant configuration: (1) active Beta redundancy (redundant circuit always active) or (2) standby Beta redundancy (alternate path essentially biased into inactivity as long as the prime path performs satisfactorily).

Assuming a failure rate of 10^{-4}/hr, the probabilities of successful operation for one year for the three configurations are found to be: 78% for standby Beta redundancy, 65% for active Beta redundancy, and 41% for the non-redundant circuit. A strong argument is presented for obtaining low degradation rates in components by operating them well below normal ratings. (Author in part)

REVIEW: While a specific problem is discussed, it is presented in a broadly useful way. General expressions for the probability of success as a function of time are given for each of the three cases. These functions assume constant failure rates which may limit their application. Although it might be argued that the failure rates for lightly stressed components are negligibly small, the continuous deterioration of some components under ionizing radiations encountered in space cannot be ignored. Overall, the paper is a useful discussion of the enhancement of reliability through the use of redundancy. The derating of components does not always decrease their failure probability; the specific case should always be checked to be sure that the failure rate is actually reduced. (The author does not explain the meaning of the term "Beta" in the context in which he uses it throughout the paper.) ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1672
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Effect of multiload switching on microminature relay contacts

AUTHOR: Adolph Bodamer, Chief Engineer, Babcock Relays

SOURCE: Electrical Design News, vol. 9, February, 1964, pp. 88-101

PURPOSE: To discuss contact performance of relays, with emphasis on the effects of different load levels.

ABSTRACT: The interdependence of contact resistance, contact erosion, contact welding, contact bounce, and contact contamination are discussed in relation to relay contact life. Contact resistance is defined and discussed, together with constriction resistance and film resistance.

Contact contamination is known to occur under one of the following contact conditions: (1) nonswitching, open contacts: chemical reaction between ambient atmosphere and contact material, (2) contacts switching at dry circuit levels: organic molecules are chemisorbed on contact surface; these are then polymerized by friction, (3) the effect on load-switching contacts is divided into two sub-groups: (a) activation--organic films adsorbed on the contact surface are partially burnt in the arc, carbon is formed, and the minimum current for arcing is reduced, (b) formation of insulating layers-- this occurs when the organic compounds are not fully carbonized. The prevention of contact contamination is also considered.

A design for a universal contact is proposed. This design has proved to be very efficient and reduces some of the problems encountered with standard contacts.

REVIEW: This is an interesting introductory paper with some state-of-the-art information. One criticism is that the section on film resistance is unnecessarily confusing because of the use of the symbol ρ for the specific resistance of the film where the dimensions of ρ are ohm-cm^2. Normally ρ, the resistivity, has dimensions of ohm-cm and is synonymous with specific resistance. There are eight useful references to the literature. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1673 -1
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability engineering in Russia

AUTHOR: Major Paris N. Keriakou, U. S. A. F.

SOURCE: Evaluation Engineering, vol. 3, May/June, 1964, pp. 6-8, 10, 12, 14, 16, 18, 20

PURPOSE: To review the state of reliability engineering in Russia.

ABSTRACT: The Soviet Union has placed considerable emphasis on the development of reliability engineering since 1955. This study shows that the overall current Soviet reliability engineering capability, as revealed in the open literature, lags the U. S. by three to five years. The Soviets have encountered numerous problems during the evolution of reliability engineering. They are changing their production goals from purely quantitative, to both quantitative and qualitative. The significant achievements in the exploration of space enjoyed by the Soviet Union are in direct contrast to the low quality non-military goods currently produced. Therefore, it is believed that the Soviet military industry is autonomous and has the highest priority for reliability efforts.

The Soviets possess the capability to develop the theory associated with reliability engineering; however, they are experiencing difficulties in bridging the gap between theory and practice. Soviet military reliability achievements are based on the use of craftsmanship for the production of parts and components, the use of simple and proven parts, and the employment of redundancy techniques whenever possible. It is concluded that within the next three to five years the Soviet Union will make considerable progress in the field of reliability engineering. The tendency will be to depart from the brute force techniques and to approach more sophisticated methods for achieving maximum reliability.

Reliability in the Soviet Union is an outgrowth or an extension of quality control caused primarily by the complexity of modern equipment. There is no clear-cut break in the time period between quality control emphasis and the beginning of reliability engineering, since many prominent mathematicians and engineers who have pioneered reliability in the Soviet Union were closely associated with quality control.

Each phase is discussed in some detail and a few summaries of important Russian articles are given. There is a bibliography of 52 items, about two-thirds of which are from Russian sources. (Author in part)

REVIEW: This paper represents an extensive piece of bibliographic research on the part of the author. The information it contains

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

is extremely interesting, since it gives us a better idea of what the "competition" is doing. One is struck by the parallel between their progress and ours--just subtract a few years from ours and you get theirs, problems and all. Specific Russian papers (translations) have been covered by Abstracts and Reviews Serial Numbers 834, 835, 859, 860, 1046, 1051, 1052, 1053, 1054, 1123, 1250, 1363, 1497, and 1498. These include several of the items cited in the bibliography of this paper. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1674
Code 800

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability engineering in other foreign countries

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 3, May/June, 1964, pp. 24-26, 28, 30

PURPOSE: To highlight the reliability engineering effort in a few foreign countries.

ABSTRACT: This report is based on interviews with key reliability engineers from Sweden, Japan, France, Germany, and England. It highlights the reliability engineering effort in these countries. In general, it appears that in most of them (except England) statistics in reliability evaluation is not emphasized as much as it is in the United States. In most of the countries, training in reliability disciplines is receiving some attention. Data exchange programs (more or less like IDEP) are functioning in several areas.

REVIEW: While this article is a highlighting and consequently gives little detail, it is quite interesting and informative. In different countries, different aspects of the problem tend to receive emphasis. An example is emphasis on the practical approach of basic engineering as opposed to emphasis on the theoretical or statistical aspects. The acid test of any approach is, of course, the results obtained in performance of equipment. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1675
Codes 802;812

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Selected reliability films--1964 updated listing--Parts I and II

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 3, May/June, 1964, p. 32 and July/August, 1964, pp. 15, 18

PURPOSE: To update the list of available films on reliability.

ABSTRACT: This list updates those published by Evaluation Engineering in 1962 and 1963 (see Abstract and Review Serial Number 925). Forty films are listed, two of which have since been withdrawn (Numbers 12 and 13). A very brief description, running time, interest group, and source is given for each film.

REVIEW: This listing should be helpful to management groups planning indoctrinational/instructional sessions. Some of the films are also very pertinent material for showing at group or section meetings of organizations such as ASQC, IEEE. This is a more extensive listing than the one referred to in Abstract and Review Serial Number 1449, although some items appear in both. The reader interested in available films in reliability and quality control should refer to both lists. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1676 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Selected semiconductor failure mechanisms and pre-failure indicators

AUTHOR: J. R. Bevington, Supervisor of Failure Physics Section, Delco Radio, Division of General Motors

SOURCE: Evaluation Engineering, vol. 3, July/August, 1964, pp. 6-8, 10-11

PURPOSE: To discuss "patterns" of failure for several common failure mechanisms found in power transistors.

ABSTRACT: Four causes of emitter-to-collector shorts in germanium alloyed power transistors are: (1) burn-through, which can be due to current overstress, junction defects, or regions of narrow base width; (2) crystal fracture; (3) regrowth spurs; (4) surface contamination. Post-failure electrical indicators of burn-through are high I_{CBO}, low V_{EB}, low V_{CEO}, identical V_{CBO} and V_{CEO} traces or a shorted V_{CEO} trace; of crystal fracture, high $V_{EB(f1)}$ and a resistive V_{CBO} trace; of regrowth spurs, breakdown in the V_{CEO} characteristic between 10 and 20 volts; and of surface contamination, degraded V_{CBO}, V_{CEO} and sometimes V_{EBO}. Physical post-failure indicators are observed only with burn-through (for which holes can generally be located, although a certain mode of current overstress failure exhibits no large, neat hole but presents rather an irregular cluster of points at which electrical breakdown has occurred) and crystal fracture.

Parameters or test measurements recommended as good pre-failure indicators are high initial $V_{EB(f1)}$; resistive, soft or unstable reverse dynamic traces of V_{CBO}, V_{CEO}, or V_{EBO}; degraded performance of any parameter following thermal cycling; the detection of any parameter lying far outside the normal distribution; and high noise generation.

REVIEW: This paper is a hasty, qualitative description of a specific failure analysis program on a specific type of transistor. Just what the "pattern of failure" concept is is never clearly stated, although the author concludes that the use of this approach can "serve as a reasonably accurate and very fast method of obtaining reliability feedback data for corrective action...within 24 hours of the detection of a problem." This may well be quite impressive, as the author evidently feels, but the reader does not know what has been done or how.

The value of the paper lies in the specific descriptions of the

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

causes of emitter-to-collector shorts. The attempt to deduce a general "pattern of failure" philosophy from these examples does not come off, and the introductory sections and summary add little to the paper.

Something seems missing from the description of "emitter crowding," as evidenced by the following sentence: "It can be shown that when the collector voltage is well below the open base voltage, the emitter current will be concentrated in a small area near the periphery of the emitter."

In a private communication the author has commented as follows: "My intention was to establish that a simple cause and effect relationship between the underlying cause of failure and post failure indicators does not always exist and that other factors must be considered in categorizing the failure mechanism. ...To overcome this overlap of cause and effect which prevents a simple categorization, I proposed that five (5) so-called "failure parameters" be considered which can be used to define a more exact set of conditions and be used to more accurately categorize a failure. The patterns of failure to which I referred were intended to be unique sets of these five parameters." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1677
Codes 782;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability in the oceans

AUTHOR: Marvin A. Dean, Electronic Systems and Products Division, Martin Company

SOURCE: Evaluation Engineering, vol. 3, July/August, 1964, pp. 19, 22, 24, 26

PURPOSE: To describe some of the special ways in which equipment for sub-oceanic purposes must be built.

ABSTRACT: Suboceanic equipment falls into three classes according to whether it is (1) protected by hulls, etc., but must have very long maintenance-free life, (2) submerged at great depths for short periods, or (3) resting on ocean bottom for long periods. Designs for the first class are handled by conventional reliability techniques. The other two require a well-planned design program to evaluate thoroughly the peculiar effects of high-pressure ocean water, fouling by marine organisms, etc. Many areas are quite lacking in engineering design and performance data since experience is so slight.

The use of statistical reliability techniques is a necessary factor in the achievement of adequately reliable equipment for underwater usage. Utilization of these statistics and data with full cognizance of their meanings and limitations can be an invaluable tool in providing economically reliable equipment. But slavish dependance on these statistics without the support of adequate engineering programs will turn out to be just wasted effort.

Under the oceans, as in other media, adequate design to withstand the stresses of the environment is preliminary to any other design consideration. (Author in part)

REVIEW: This is an introductory paper on the subject of designing for an under-ocean environment. It does not treat any phase in detail. Actually, in terms of the reliability effort, there is no need to split the equipment into three classes. A good reliability effort obviously always seriously considers the true environment and requires experimentation where this knowledge is too incomplete.

Another paper on the marine environment has been covered by Abstract and Review Serial Number 947. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1678
Codes 815;833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Evaluating tape wound cores for high reliability requirements

AUTHOR: John T. Lee, Technical Manager, Market Development, Magnetics, Inc.

SOURCE: Evaluation Engineering, vol. 3, July/August, 1964, pp. 27-28

PURPOSE: To discuss the factors important in specifying coils with tape wound cores.

ABSTRACT: A tape wound core is a magnetic structure, usually toroidal in shape, manufactured from high permeability thin gauge strip. Its selection depends greatly on the interrelationship of cost, size and required circuit performance. The selection of "the correct core" for a magnetic circuit depends upon all of these factors combined to give the most desirable results. The core must be analyzed to determine its proper size, and when wound with magnet wire, to give the correct impedance characteristics and to support the proper voltages at the frequency used.

Reliability of the circuit depends not only on the core itself and its reaction to the environmental conditions to which it is subjected, but also on the effectiveness of the magnet wire which is wound on the core. In essence, the reliability of the magnetic core structure is governed by the windings. Failures have in most cases been directly attributed to winding insulation failure due to overloading, voltage breakdown or physical abrasion.

Complete dimensional specifications are needed. Environmental tests are usually specified, but care must be used that conflicting or impossible requirements are not placed on the unit. Shock and vibration capabilities are limited not by the core material but by the method of casing. Core characteristics vary greatly with temperature and if other than 25°C (standard temperature) is specified for a test, a complete evaluation of core characteristics must be made. (Author in part)

REVIEW: This is a reasonable introduction to the subject of specifying tape wound cores. There are a few references to specifications, but the novice in this field may well have difficulty in getting enough of the right kind of information from this article. For the most part it will tell him things to watch out for.

The author, in a private communication, has made the following comment: "It is hoped that the questions left in the mind of the reader will stimulate him enough to seek further for the right kind of information necessary to solve his specific problems. Of course, most of these answers are available from component suppliers, government agencies and independent studies made under government contract." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Accuracy and rounding data (reliability mathematics corner)

AUTHOR: Irving Belson, IBM General Products Division

SOURCE: Evaluation Engineering, vol. 3, July/August, 1964, pp. 29-30

PURPOSE: To discuss "significant figures" and rounding off of data.

ABSTRACT: Significant figures are important when analyzing and reporting the results of physical measurements. Rounding off these numbers can have important consequences on the accuracy of published data.

REVIEW: This is an extremely elementary discussion of the subject and not too well done. Most engineers are familiar with the propagation of "errors" methods, or can easily understand the derivation. The result, for $y = f(x_1, x_2, .., x_n)$, is

$$\overline{\Delta y}^2 = \sum_{i=1}^{n} (\partial f/\partial x_i)^2 \overline{\Delta x_i}^2 ,$$

no matter what the arithmetic involved, and is true as long as the errors are small--an important restriction on the entire discussion. The author seems to confuse arithmetical numbers (the exact fractions 7/9 and 9/7) with the results of a measurement--a most unfortunate circumstance.

All in all, the article contributes little--better discussions of this topic may be found in most elementary statistics and physics textbooks. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1680
Code 555

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Spare parts reliability nomograph (reliability mathematics corner)

AUTHOR: N. J. Elias, Automatic Electric Company

SOURCE: Evaluation Engineering, vol. 3, September/October, 1964, p. 16

PURPOSE: To show how to calculate spares requirements for a system with an "exponential" failure rate.

ABSTRACT: The number of failures of a completely debugged system has a Poisson characteristic, i.e., the hazard function λ is a constant. The probability of n or less failures in T hours is given by a sum of Poisson terms. Since this is difficult to solve, a nomograph is given, with two examples showing its use.

REVIEW: While the nomograph was not checked, the equation is correct. The nomograph should make solution of the problem easy. It is important to remember that not all systems have Poisson behavior. Further, even if the system has a Poisson behavior, Part A or Part B may well not have Poisson behavior. In many instances, however, the amount of information available is not sufficient to justify a more complex hypothesis and the analysis will give ball-park figures.

It should be noted in passing that the equation is easy to solve since it can be transformed. The cumulative sum of the terms of the Poisson series is easily expressible in terms of the chi-square distribution, as pointed out in [1], p. 10. Thus with chi-square tables it is easy to find the confidence for a given n, and vice versa. For some reason, this relationship does not seem to be too well known to workers in reliability.

(In the nomograph, there are two dotted lines which, one would suspect, correspond to the two examples. However, they do not. In fact, the two examples turn out to be essentially one, since the expected number of failures is the same in both cases.)

REFERENCE: [1] Biometrika Tables for Statisticians, Volume 1, edited by E. S. Pearson and H. O. Hartley, Cambridge University Press, 1956 ##

Serial Number 1681
Code 833

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Connectors and reliability -- 1964

AUTHOR: (Editorial Matter)

SOURCE: Evaluation Engineering, vol. 3, September/October, 1964, pp. 17-20,22-24,26,28,30,32,33

PURPOSE: To report on a round-up of connector developments.

ABSTRACT: Connector reliability is difficult to define and to measure. An EIA task group recommended a life test "cycle" consisting of mating/unmating, insertion/removal of contacts, vibration and temperature "stressing" for a period of six hours. The actual failure rate for this "cycle" would then be given. The trouble is that this system does not fit in with the failure rate system (assumed Poisson behavior) now widely in use. As a partial compromise, levels A, B, C, D, and E would cover failure rates of 10%,...,10^{-3}% per "cycle". How to convert, if possible at all, from this system to the conventional one is not agreed upon.

Many industry people blame NASA for not putting some order into the field since it is many of their contractors and subcontractors who have caused the multiplicity of reliability specifications and the conflicts therein. For example some people insist on dielectric tests as being extremely important; others dismiss them as of no consequence. Another problem is that those involved in assembling the connector make stupid errors--which are later attributed to connector unreliability.

In general, an evaluation engineer must carefully weigh each firm's statements (as always) and verify the important ones before making a decision.

The views of over a dozen connector companies are summarized in the last part of the article, company by company.

REVIEW: While the connector people think their problem is unique, it probably is no worse than, for example, the problems associated with gyros. This is not to minimize the problems they have--just to put them in perspective. Connectors are not the only component for which Poisson behavior is decidedly not applicable and the deviation from the conventional MTBF or λ type specification is going to be made sooner or later by someone. Thus, it should not overly concern the connector manufacturers that they will be first.

This is a good review article and the views of the individual companies are interesting. One wonders who causes all these problems, since the glowing advertisements of connector manufacturers imply that there need be no reliability problems in connectors. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1682
Code 873

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Improving connector reliability through proper maintainability

AUTHOR: William Jensen, Executive Vice President, Methode Electronics, Inc.

SOURCE: Evaluation Engineering, vol. 3, September/October, 1964, pp. 34-35

PURPOSE: To discuss, through a question-answer format, the proper maintenance of connectors.

ABSTRACT: Most service technicians do not realize the delicate nature of connectors (or pay no attention) and treat them too roughly. Service men should be instructed and trained in this regard. Designers of equipment can help by locating connectors for easy access and checking and by not putting them where they are convenient ladder steps, etc. "Idiot-proofing" is only a partial solution since it is difficult, expensive, and must be directed toward specific applications. The lack of proper specifications and undue cost-cutting can lead to gross misapplications. (A checklist is provided for specifying connectors.)

REVIEW: The points made here are all good ones. The idiot-proofing of equipment could probably be carried further if everyone concerned considered it really necessary. For example, consider the car or vacuum cleaner designer who stubbornly refused to design for the treatment the customer gives his product, saying instead--they ought to be educated to use it right; how far would his product go? Ruggedizing can be done, although one may have to sacrifice nominal performance, etc. in order to achieve it. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1683
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Connector failure modes

AUTHOR: Adrian Van Keulen, Engineering Services Manager, Cinch Manufacturing Company

SOURCE: Evaluation Engineering, vol. 3, September/October, 1964, p. 39

PURPOSE: To define and list causes for the three failure modes of connectors.

ABSTRACT: The three failure modes for connectors are

1. Dielectric failure: a marked increase in the flow of current between terminals or to ground as evidenced by a drop in insulation resistance. Ten possible causes are listed.
2. Current interruption failure: an interruption (temporary or permanent) of current flowing through the mated contacts or a marked reduction in current flow as evidenced by an increase in contact resistance. Six possible causes are listed.
3. Mechanical damage failure: any permanent physical damage which impairs the function of the connector. Four possible causes are listed.

REVIEW: These definitions, at least when interpreted broadly, seem to include most connector troubles, degradation as well as catastrophic. Those concerned with connector design and application may find this list of use. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1684
Codes 813;815;816

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Materials reliability program for resistors -- a case history

AUTHOR: Glenn W. Carter, Director of Advanced Engineering, Dale Electronics, Inc.

SOURCE: Evaluation Engineering, vol. 3, September/October, 1964, pp. 42-43

PURPOSE: To show that component manufacturers must control the quality of incoming material, rather than merely inspect it.

ABSTRACT: Just as equipment manufacturers had to go back to component suppliers and institute corrective quality programs, so must component manufacturers go back to their materials suppliers and see that corrective, effective quality programs are instituted. Otherwise they cannot make a very high-reliability product. The example described in this paper pertains to wirewound resistors. Wire suppliers are traditionally rather independent, but with sufficient encouragement they have instituted high-quality procedures in their plants. Resistor failures due to faulty wire have dropped markedly.

REVIEW: The case history given here appears quite reasonable. One would hope that as competition among the materials suppliers becomes directed toward quality, that one could return to the specification/guarantee type of buying with the assurance that the supplier was conscientious and well informed. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Fault detectability by the maintainability figure of merit technique

AUTHOR: John E. Rutledge, Jr., Applied Physics Laboratory, Johns Hopkins University

SOURCE: Evaluation Engineering, vol. 3, September/October, 1964, p. 46

PURPOSE: To present a fault detectability figure of merit.

ABSTRACT: A design can be rated with respect to ease of detecting faults. The following system is proposed:

Time	%	+	Talent	%	+	Test Equipment	%
None	50		Unskilled	25		None	25
Short	25		Semi-skilled	15		Common	15
Long	15		Skilled	10		Special	5

(Percent based on engineering experience and judgment)
Fault detection figure merit = Time + Talent + Test Equipment. An average figure of merit over all components can easily be calculated.

Four examples are given. This is a procedure similar to that for a maintainability figure of merit in the paper (by the same author) covered by Abstract and Review Serial Number 1609.

REVIEW: Without extended use of the system, its usefulness is difficult to evaluate. It is a quick method and should likely find application in many areas where something "quick and dirty" is needed. The value of "quick and dirty" procedures is not to be underestimated. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliable electron beam welded micro-connections

AUTHORS: D. J. Garibotti, United Aircraft Corporation, Hamilton Standard Division, Electronics Department, Broad Brook, Connecticut and W. V. Lane, United States Army Electronics Research and Development Laboratory, Fort Monmouth, New Jersey

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 81-97, August, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

PURPOSE: To describe a series of tests on copper-nickel welded micro-connections.

ABSTRACT: Electron beam joining techniques with associated fixturing have been employed to develop a high termination-density interconnecttion system--micro-assembly stack--for the integration of microminiaturized electronic components of the thin film and integrated circuit variety. The interconnecting system embodies ten stacked wafers--0·6 x 0·6 x 0·030 in.--joined by means of peripheral conductor ribbons on all four sides, yielding a structure with 80 interwafer conductors and 800 electron beam-welded joints on 0·025 in. centers. The interconnection technique is suitable for application to most any wafer dimension and geometry.

The reliability of the process was demonstrated in terms of the mechanical and electrical characteristics of the interconnections in the as-welded condition, and also after environmental exposure. Pull strength tests were carried out on the copper ribbons welded to the metallized edges of individual wafers as well as to wafer-assemblies simulating conditions in a micro-assembly stack. In the latter instance the pull tests were carried out on weld pairs. The salient points of the reliability study are presented below.

Pull strength. Statistical analysis by normal (Gaussian) distribution methods of the weld pair pull strengths indicate at a 90 per cent confidence level that no more than 2·6 welds per 200,000 from such a population would fail below 200 g. All the welds failed in the copper conductor immediately adjacent to the fusion zone. All pull strength values exceeded 200 g.

Weld resistance. It was demonstrated at a 90 per cent confidence level that no more than three welds out of 1000 weld pair joints from the same population as above would have a resistance greater than 0·010Ω.

Thermal shock. Weld pairs subjected to thermal shock did not exhibit any pull strength degradation. From the statistical analysis of the resistance measurements it was computed that no more than 4.5 welds out of 1,000,000 from such a population would increase more than 0·001Ω.

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

Extreme ambient temperature test. Weld pair joint resistance was measured from -55°C to 200°C and all measurements were found to be well below 0.010Ω.
Vibration tests. Two micro-assembly stacks were vibrated according to Method 204B of MIL Std 202A without any visible degradation.

A modular interconnection system for the integration of thin films, solid state devices and hybrid microcircuits has been developed. This system, based on an electron beam-welded joint of demonstrated reliability, provides a termination and conductor density capability compatible with the high parts density of microcircuits. (Authors)

REVIEW: This is a rather complete description of the series of tests and the results from them. While the method has been demonstrated to be feasible, no extensive production data are referenced. The number of visually defective welds (and thus not tested) is not mentioned. The use of the Gaussian distribution for calculations into the tail regions with probabilities less than 0.3% should be qualified, since it is obviously not proved that the distribution is exactly Gaussian and it may deviate considerably from that shape in the regions well removed from the mean. Nevertheless, the method does appear to be promising.

The author, in a private communication, has contributed the following remarks:

"1. Insofar as production is concerned, a pilot facility is in the final stages of assembly for the fabrication of 100 EMM's per 8-hour shift. Each unit comprises 380 microconnections of the type described in the referenced report. Prior to the establishment of this pilot production facility numerous modules, again using the same type of microconnections, have been fabricated and successfully subjected to all military environmental tests. Consequently data on production-like environments is rapidly becoming available.

2. The yield of the overall process as established by removal of the defective welds (visual inspection) has resulted in a 95% yield.

3. The data described in the report has been analyzed by nonparametric techniques and it was concluded that at a 90% confidence level that less than 3 welds out of a thousand would fail below 200 grams. The same arguments hold for the resistance measurements; that is, less than 3 welds out of a thousand would have a resistance in excess of .010 ohms.

In conclusion, fabrication of microconnections by electron beam welding is a practical and reliable process which has been adopted for the interconnection and packaging of microcircuits on a production basis." ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1687 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Accelerated life testing and over-stress testing of transistors

AUTHOR: J. M. Groocock, Standard Telephones and Cables Ltd, Footscray, Sidcup, Kent (England)

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 191-204, December, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

PURPOSE: To examine the applicability to transistors of accelerated life and over-stress testing and to compare them with conventional test methods.

ABSTRACT: Telecommunication equipment may be required to function for 20 years or more and transistor failure rate requirements may be as low as 10^{-8} to 10^{-9}/hour. Complete proof that a transistor has a specified reliability in a particular equipment is established only when successful operation of the devices in that equipment for the required period has been achieved. If the test period requires, say, five years, the information has no direct practical value because it is not available at the time when decisions regarding suitability must be made. Further assumptions are made in using conventional life tests, such as that devices bought for use have the same reliability as those tested, that the operating conditions of the test apply to the actual circuit, and that the reliability figure based upon a given number of "life-test hours" will apply even when the use period is longer or shorter than the test period.

Failure of a transistor on life test or in operation is a result of its changing over a period of time from one thermodynamic state, the initial state, to the failed state of lower free energy. The rate at which this change occurs is usually temperature-dependent, and this dependence can often be expressed by the Arrhenius equation. An alternative equation, which has a sounder theoretical basis, is the Eyring equation. However, the Arrhenius equation is easier to use in that it leads to a linear relationship between log (time-to-failure) and the reciprocal of absolute temperature. More than one failure mechanism may apply, in which case the predictions made from accelerated life tests and using the Arrhenius equation may be optimistic.

The use of the Arrhenius equation is exemplified by some results obtained by storage at 100°C, 115°C, and 135°C of three samples each of 24 transistors drawn from the TED540 product line. These pnp alloy transistors have a storage rating of 75°C. Making the two assumptions that the Arrhenius equation is followed and that the failure distribution is log normal, the agreement between cal-

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

culated and experimental results is quite good. Other results from electrical and mechanical stressing are also presented.

Some failures are rogues, and do not follow the Arrhenius relationship. However many of the rogues result from mechanical defects and mechanical over-stress testing can give valuable information. This in turn might be used to improve the device with consequent elimination of some of the rogues.

In summary the actual failure rates occurring at normal stress levels may be markedly higher than those predicted because the quantitative relationship between stress and failure has not been determined correctly or because failure modes are there whose presence has not been revealed by the accelerated tests. For this reason it is clearly desirable to integrate accelerated tests and long-term, large-sample tests.

REVIEW: This is a very good paper and shows the balance between guiding principles, theory, results, and interpretation. The relationships existing between the various forms of overstressing and step-stressing are noted and evaluated. A limited bibliography is included.

See also the papers covered by Abstracts and Reviews Serial Numbers 1457 and 1689. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1688
Code 838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Open and short circuit failure of hammock networks

AUTHOR: D. V. Blake, Ship Division, National Physical Laboratory, Faggs Road, Feltham, Middlesex (England)

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 205-206, December, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

PURPOSE: To outline a method of calculating the probability of failure of a hammock network for any combination of open-and short-circuit failures of its components.

ABSTRACT: A common method of using redundancy to improve reliability is to use a number of components arranged as a "hammock" network (bridge circuit) whose over-all properties are similar to those of its components. This was first studied by Moore and Shannon for nets of relay contacts. It is not generally realized that this work can be extended to determine the probability of failure of any network of passive elements for given probabilities of open-or short-circuit failure of its elements.

Three networks, derived from the bridge circuit, are used to illustrate this extension; the first has an open circuit between the two branches, the second has a short there, and the third has an element the same as the other four connected between the two branches. The first part of the paper considers the case of an element being either short or open. The last part considers networks of passive elements which either (a) work normally, (b) have probability R of being an open circuit, or (c) have probability S of being a short circuit. It is further assumed that any combination of elements working normally will also work normally. It can then be shown that the third type of network is always more reliable than the other two (but see REVIEW, below). The general method of calculation used here is far easier than considering all possible states of the network.

REVIEW: This is a short but generally good paper, easily followed to concisely stated conclusions. The conclusions would appear to lend themselves to other situations in which failure can be reduced to go--no-go operations, hence should be of rather broad interest. Some of the theorems are not obvious to those unacquainted in detail with the Moore and Shannon work (for which the reference is cited in the paper).

The statement that the third type of network is always more reliable than the other two is subject to the restriction $R \approx S \ll 1$. However the paper implies the superiority of the third type of network regardless of the relative magnitudes of R and S. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1689 -1
Code 844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: The step stress method of accelerated life testing

AUTHOR: J. Honeychurch, Quality Assurance Department, Texas Instruments Ltd., Bedford (England)

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 215-225, December, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

PURPOSE: To examine step stress testing as a means for obtaining reliability information and for the determination of failure modes.

ABSTRACT: To establish high levels of reliability in semiconductor components by normal life testing requires either large numbers of devices or long periods of time. "Step stress" testing is one method of reducing the time required and at the same time reducing the cost of testing. In addition to establishing the level of reliability, it can aid in the determination of failure modes and the evaluation of devices, i.e. comparison between types or lots of a device. This paper discusses the theory, experimentation and results obtained by performing temperature step stress experiments on the 2G102 germanium mesa transistor and the 2G302 germanium alloy junction transistor and dissipation stress results on the 2S001 silicon grown junction transistor.

There are two ways of performing step stress experiments, one of which involves fixing the time interval and varying the stress (temperature, power dissipation, shock, etc.), while the other utilizes fixed stress and variable time. The latter could give no reduction in total time over conventional methods.

Several restrictions hold, chief among them being that the values of the transformed variables in stress and time are Normal, that the standard deviations of the transformed variables are constant from interval to interval, and that the acceleration curve is a straight line which can be extrapolated to lower stresses. Typical transformations may be 1/T for temperature and log t for time. The relationship then may be expressed as $1/T = m \log t + C$.

This equation is obtained on the assumption that the failure mechanisms, although probably complex, can be treated in the same way as most chemical reactions, the rate increasing with the increase in temperature. One relationship which is widely used to describe temperature-dependent chemical reactions is the Arrhenius equation.

Acceleration curves and probability plots are obtained for each of the step stress test conditions. Although much of the data did fit the predictions, both technique (excessive handling) and

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

time for the intervals appeared to affect the result. For example, in testing the 2G302, the one-and two-hour time interval probability plots led to straight lines; in testing the 2S001, departures from normality were observed at the lower end for the four-hour plot and at both ends for the eight-hour plot. An activation energy of 1.17 ev was obtained from the slope of the acceleration curve for the 2G302. This appears to be reasonable.

A failure in ball bonds was revealed in step stress testing of some solid circuit networks. Revision of the bonding technique was successful in improving the reliability of later runs.

REVIEW: This paper invites comparison with a paper by Groocock (see Abstract and Review Serial Number 1687). In the present work the area of concern is more restricted, the mathematical treatment is considerably more extensive, and the results are more specific. It suffers from a narrowness of viewpoint which restricts the interpretation of the results, particularly where they depart from the simple theory. The testing procedure is not as clearly specified as it might have been, making the interpretation of the method for displaying the results somewhat confusing. The correction of results for accumulated stress from previous steps is analyzed, and criteria are set forth for conditions under which such corrections are negligible factors.

Errors noted include lack of a Centigrade temperature scale on two of the figures (5 and 6) as specified in the body of the text, and the identification in the text at one point of Fig. 10 as a two-hour interval plot while in the caption and in another part of the text it is identified as a four-hour time interval plot.

Especially when read with other papers in this area, this is a useful contribution for its specific discussions of acceleration slopes, activation energies, and corrections for previous stress steps. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1690
Codes 090

835;844

090

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability bibliography

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 135-153, August, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

This is a bibliography listing about 700 papers and reports dated for the most part between 1950 and 1960. They are grouped under the following 14 headings. Under each heading the papers are listed alphabetically by author.

1. General Reviews
2. Reliability of Equipment--Civil
3. Reliability of Equipment--Military
4. Valve Reliability
5. Transistor Reliability
6. Component Reliability
7. Circuit Reliability
8. Environmental Conditions
9. Design and Constructional Techniques
10. Sampling, Quality Control, Statistics, Etc.
11. Maintenance
12. Reliability Testing
13. Reliability Prediction
14. Human Engineering

TITLE: Thermal characteristics of potted electronic modules

AUTHORS: J. I. Gonzalez and C. E. Waugh, Martin Company, Orlando, Florida

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 179-190, December, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

This paper is the same as the one covered by Abstract and Review Serial Number 701.

TITLE: Bibliography on redundancy techniques

SOURCE: Electronics Reliability & Microminiaturization, vol. 2, pp. 247-251, December, 1963 (Pergamon Press Limited, Headington Hill Hall, Oxford, England and 122 East 55th Street, New York 22, New York)

This is a listing (in author alphabetical order) of approximately 200 papers on the theory and methodology related to redundancy. The bulk of the material is dated between 1954 and 1962. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1691
Codes 814;838

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Determining the optimum number of repairable redundant subsystems

AUTHOR: Harry Gildea, Management Systems Corporation, Cambridge, Massachusetts

SOURCE: Proceedings of the IEEE, vol. 51, pp. 1153-1154, August, 1963 (correspondence)

PURPOSE: To determine the number of repairable redundant subsystems for minimum present-value cost of the system.

ABSTRACT: In a recent article (see Abstract and Review Serial Number 719), Einhorn developed equations for predicting the mean time to failure and mean down time for a system including redundant subsystems in active standby status. From these reliability equations, it is possible to determine the economically optimum number of repairable redundant subsystems which should be acquired and maintained.

The equations take into account the time value of money by discounting future costs. The approximation is made that each failure occurs at multiples of the MTTF. Since the equations are complicated, no explicit solution is given.

REVIEW: The main contributions of this letter are that it (1) reminds readers of the desirability of minimizing total costs, and (2) emphasizes that the time value of money (interest on investment) may be significant in cost calculations.

Other papers on calculating net system costs have been covered by Abstracts and Reviews Serial Numbers 903, 1199, 1234, 1271, 1297, 1298, and 1303. ##

Serial Number 1692
Code 837

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Reliability vs component tolerances in microelectronic circuits

AUTHORS: P. W. Becker and R. E. Warr, General Electric Electronics Laboratory, Syracuse, New York

SOURCE: Proceedings of the IEEE, vol. 51, pp. 1202-1214, September, 1963

PURPOSE: To present a method for determining optimum component tolerances with respect to allowable temperature range of operation.

ABSTRACT: It is well known that the reliability of a circuit can be increased by designing it for worst-case conditions so that, even if component characteristics drift, the circuit will still operate satisfactorily. However, it is shown in this paper that extreme worst-case design can lead to increased operating temperature and, therefore, again reduced reliability. A method, illustrated by two practical examples, is indicated to find the compromise in component and circuit design tolerances leading to maximum reliability at any specified time or over any specified time interval. (Authors)

REVIEW: The title refers to an important topic although the discussion is by no means limited to microelectronics. The thesis is not actually proved from an explicitly stated model, but is both implicitly postulated and demonstrated by an example. The reference (see Abstract and Review Serial Number 45) given for the statement that increased tolerances result in increased power dissipation does not actually prove the theorem but merely gives an heuristic outline of it. It is likely, however, that the statement is true in many practical cases.

The classification of failures into drift and catastrophic is not clear-cut, nor is the description of drift failures adequate since only reversible changes are considered.

The authors claim to have excluded second-order effects, but give no indication of what effects are second order.

In general, the paper is an example of what can be done--and is good in that respect--rather than a proof of a quite general situation, since rigor and exactness in many statements are quite lacking. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1693
Code 820

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Concerning reliability prediction

AUTHORS: C. A. Combs, Jr. and J. H. Wujek, Jr., General Electric Company, Computer Department, Phoenix, Arizona

SOURCE: Proceedings of the IEEE, vol. 51, p. 1248, September, 1963 (correspondence)

PURPOSE: To reply to a satire on reliability calculations.

ABSTRACT: Statistical confidence statements are not as capricious as is suggested in the letter covered by Abstract and Review Serial Number 720. They are well-defined and necessary for a proper understanding of the meaning of statistical interval estimates. While reliability prediction is still largely in a qualitative state, there is no reason to believe it will not mature.

REVIEW: How much of a reply the original letter (see Abstract and Review Serial Number 720) deserves depends on how seriously one thinks it was meant. Most of the comments here are straightforward, although reliability prediction may well not become an exact science as soon as many of us would hope. There are grave inherent difficulties with all of the present and proposed methods --they are usually too complicated, too expensive, or too inaccurate. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1694
Codes 711;714;844

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS

TITLE: Cracking in iron-nickel-cobalt alloy wire

AUTHORS: R. G. Baker and A. Mendizza, Bell Telephone Laboratories, Murray Hill, New Jersey

SOURCE: Electro-Technology, vol. 72, October 1963, pp. 11-12

PURPOSE: To describe experiments on wire of the Kovar/Rodar type for determining its susceptibility to stress-corrosion cracking.

ABSTRACT: The dominant fact emerging from this investigation is that Fe-Ni-Co alloy wire of the Rodar type is indeed susceptible to stress-corrosion cracking in the as-received, raw condition. All that seems to be necessary is sufficient stress and a corrosive agent, which might be condensed water vapor. Cracking is apparently preceded by only minute amounts of rust. The various thermal treatments, the diffusion of copper into the surface grain boundaries, and the gold finish do not play a major part in the corrosion process. They may, however, accelerate it. Gold, particularly, has a galvanic effect at coating discontinuities caused by the wire-wrapping operation. Hydrogen embrittlement is not a factor in the cracking of Rodar.

Stress-corrosion cracking of Rodar leads can be prevented if the entire surface of the lead is coated with a suitable material. Hot solder, properly applied, is a satisfactory coating. If applied over a gold finish it provides, in addition, a certain degree of lubrication so that tensile cracking of the basis metal can be almost completely eliminated. (Authors in part)

REVIEW: Papers such as this on modes and mechanisms of failure are very worthwhile. This one appears to be well written and to describe good research. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546

Serial Number 1695
Code 838

R E L I A B I L I T Y   A B S T R A C T S
A N D   T E C H N I C A L   R E V I E W S

TITLE: How much does redundancy improve reliability?

AUTHORS: M. W. Burt and D. C. James, The Martin Company

SOURCE: Control Engineering, vol. 10, pp. 71-76, June, 1963

PURPOSE: To provide an explanation of the principles and pitfalls of applying redundancy.

ABSTRACT: Basic (non-redundancy) approaches to increasing reliability such as simple vs. complex circuits, highly-reliable components, and derating of components are an essential step before redundancy is tried.

Equations for the probability of success are given for series, parallel and series-parallel circuits. The ratio of the number of failures by opening to the number by shorting is an important parameter and helps to determine which type of redundancy is best. Several curves are shown.

Majority voting is discussed and some equations are given.

A big problem in redundancy is how to tell that all elements are working at the beginning. Several approaches are listed.

REVIEW: The discussion of ordinary redundancy and ways to improve basic reliability is good. (The notation is somewhat unusual, and thus equations may look different.) It is difficult to interpret the notion of open and short failure on anything but a two-terminal device. Thus, its application to majority voting devices is not at all clear. A good discussion of majority voting and probability of success is given in the paper covered by Abstract and Review Serial Number 1268. In that paper, the probabilities of a circuit's failing to "0" or "1" are considered. It turns out that the voting and calculating circuits cannot be treated independently.

The discussion of detecting element failure in redundant equipment is brief but good. ##

Prepared by
RESEARCH TRIANGLE INSTITUTE
Post Office Box 490
Durham, North Carolina 27702
Contract Number NASr-40

Sponsored by
OFFICE OF RELIABILITY AND QUALITY ASSURANCE
National Aeronautics and Space Administration
Washington, D. C. 20546